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Sewage Research

STUDIES ON THE METHANE-PRODUCING BACTERIA

III. DIGESTION OF SEWAGE SOLIDS BY THE ADDITION OF ENRICHED CULTURES OF METHANE-PRODUCING ORGANISMS *

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Introduction

Up to the present time the usual way of initiating methane fermentation in sludge digestion has been to develop the organisms in the fresh solids by holding the solids for a protracted period and by making the environmental conditions, such as temperature and reaction, favorable for the development of the organisms. This universal practice, though very useful, is wasteful of time and space and from a bacteriological standpoint is unsound. Most industrial bacteriological processes are carried on by cultures of specific organisms under controlled conditions to bring about the desired reactions, to insure uniformity of product, efficiency of process, and to prevent upsets in the process.

The development and maintenance of active cultures of methane-producing organisms by present practice is quite uncertain. Furthermore, the environmental conditions favorable for overall digestion may not be ideal for the gasification stage. Therefore, by segregating the gasification from the liquefaction stage and by making environmental conditions ideal for each process, better efficiency may be expected. Since the methane fermentation is the slower, more critical and important stage of digestion it was considered advisable to undertake a study of isolating and culturing the methane-producing organisms before attacking the problem of liquefying organisms. The methods of isolation and enumeration of these organisms have already been published in Part I of this series. Part II dealt with the correlation of the numbers of methane organisms in digesting sludges with gasification. The present paper deals with the addition of enriched cultures of these organisms for the purpose of stimulating digestion.

Experimental

Enriched cultures of the methane-producing organisms were obtained by inoculating the organisms into the synthetic culture medium previously described.[1] The addition of asbestos to the synthetic medium was found to be desirable. It was shown [2] that the methane-producing organisms

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. of Water and Sewage Research.

tend to accumulate in the sludge phase of digesting solids. This may be due to the necessity for attachment to a solid surface. Asbestos serves as an inert carrier since it forms shreds and gives a large surface area. The amount of enriched culture added to the sewage solids could be varied by utilizing varying amounts of asbestos.

Bottles containing the desired amount of asbestos were filled completely with the medium, plus a previously enriched inoculum of the appropriate organisms, and stoppered with tightly fitting glass stoppers to exclude the air and maintain anaerobic conditions. The volume of medium fed to various asbestos cultures was as follows:

Asbestos Grams	Volume of Medium Cu. Cm.
2.5	300
4.0	500
7.5	500
10.0	1000
15.0	1000

At the peak of gas production the liquor was decanted and fresh medium added to the asbestos culture in the bottle. Each culture received three such transfers before it was used to inoculate sewage solids. It generally required 4 to 6 days for the ethyl alcohol-fermenting organisms to reach a peak of gasification and from 6 to 8 days for the acetate- and butyrate-fermenters. All incubations were at 32° C.

The acetate-, butyrate- and ethyl alcohol-fermenting methane organisms were enriched in this way separately by feeding the cultures with the respective organic materials. The amount of culture added to the sludges was varied by adding different amounts of asbestos cultures (on a dry weight basis). The supernatant liquor was decanted from the asbestos culture and organisms retained on the asbestos were then added to the various sludges. Where a "mixture of organisms" was used an equal amount of each of the three asbestos cultures was taken, *e.g.*, in the series to which 2.5 grams of a single organism on asbestos was added to a portion of sewage solids, the "mixture" contained 2.5 grams of each culture. The numbers of methane-producing organisms in the enrichment cultures were determined when gas production was proceeding quite vigorously since this was the point at which the cultures were used for inoculation. Cultures containing 2.5, 7.5 and 10.0 grams of asbestos were counted in the first, third, and fourth transfers in the following manner: When ready for enumeration the supernatant liquor of the cultures was removed and replaced by sterile media. This was then shaken vigorously in order to disperse the organisms attached to the asbestos as much as possible. Counts of the numbers of organisms present were made in the manner described in a previous paper.[2] At times difficulty was encountered due to clogging of the pipette by the asbestos. The numbers of organisms obtained are given in Table I.

The results presented in Table I show that there was a considerable increase in the number of organisms with each successive transfer. The

third and fourth transfers gave approximately the same counts, indicating that maximum numbers had been attained by three transfers. The cultures were, therefore, used to inoculate the various sewage solids after the third transfer. It should be noted that the ethyl alcohol-fermenting organisms were built up to a higher concentration than the other two cultures. The ethyl alcohol-fermenters were present in the third and fourth asbestos cultures in concentrations up to 30 to 40 billions per gram of asbestos. Furthermore, the numbers of organisms per gram of asbestos were practically the same with the different amounts of asbestos employed. Variations in counts were probably due to the high concentration of organisms in the culture and difficulty of sampling in the presence of asbestos.

TABLE I.—*Number of Methane-producing Organisms in Millions per Gram of Asbestos in the Enrichment Cultures at Peak of Gasification of the First Inoculation and after Third and Fourth Transfers*

Amount of Asbestos	Acetate-Fermenters	Butyrate-Fermenters	Ethyl Alcohol-Fermenters
Initial culture			
2.5 g.	280	100	1,700
7.5 g.	270	80	1,600
10.0 g.	200	130	2,500
Third transfer			
2.5 g.	1,000	520	36,000
7.5 g.	933	660	33,000
10.0 g.	1,300	600	25,000
Fourth transfer			
2.5 g.	800	480	28,000
7.5 g.	933	660	40,000
10.0 g.	2,000	600	30,000

Seeded Solids.—Fresh solids were prepared by grinding settled sewage solids in a household garbage grinder. The ground solids were treated in various ways as indicated and then divided into five portions, which were treated as follows: one portion received a mixture of all three organisms, three portions received the three organisms individually and the fifth served as a control. The control consisted of an equal amount of asbestos as in the inoculum, minus the organisms, added to the fresh solids. All sludge digestions were carried out at 23° C.

A fresh solids-ripe sludge digestion mixture was prepared on a 2.2 : 1 ratio based on dry volatile matter content. The mixture contained:

250 c.c. fresh solids..... 4.2% solids, 70% volatile matter
250 c.c. ripe sludge..... 2.4% solids, 55% volatile matter

To portions of this seeded material there was added 4.0 and 7.5 grams of the asbestos, containing enriched cultures of the methane-producing organisms.

The results obtained show that the addition of methane-producing organisms to seeded solids had only a slight acceleratory effect on digestion. Gas was produced at practically the same rate in the control sample, to which no culture was added, as in the samples to which methane-producing organisms were added. In each instance digestion was completed in from 18 to 19 days. Thus it was considered useless to undertake further work on the acceleration of digestion of seeded solids by the addition of enriched cultures.

Limed Solids.—Three different batches of solids were obtained at various intervals from primary sedimentation tanks. These were limed daily to pH 7.2 to 7.8 until the pH value did not decrease. The solids were then divided into different portions and inoculated with enriched cultures of methane-producing organisms. The initial solids and volatile matter content of the different batches of fresh solids and the amount of asbestos cultures added are given in Table II. The inoculum of asbestos

TABLE II.—*Solids and Volatile Matter Content of the Different Batches of Fresh Solids and the Amounts of Asbestos Used*

	Solids Per Cent	Vol. Matter Per Cent	Asbestos Used (Grams)	
			Per 100 c.c. of Fresh Solids	Per 100 gms. of Volatile Matter
Batch I	4.5	71.0	.38	12.1
Batch II	4.6	64.0	.72	24.7
			1.36	46.1
Batch III	4.0	73.0	1.66	57.1
			2.50	85.6

cultures is expressed on the basis of the individual cultures added. When the three cultures were added together the amounts of asbestos were three times as much as in single cultures.

The effect of the addition of the various amounts of the different cultures and the mixture of cultures on the gas production is shown in Fig. 1. It is evident from the curves that the addition of cultures increased (1) the rate of gas production and (2) the amount of gas produced. Of the individual cultures the addition of organisms capable of fermenting ethyl alcohol was least effective. In some instances the addition of acetate-fermenting organisms was more effective than the butyrate-fermenting organisms whereas in other cases, vice versa. The addition of the mixture of the three cultures was most effective from the standpoint of both rate and amount of gas produced. It should be remembered, however, that in the mixture of three cultures each of the types of organisms was present in the same approximate numbers as when added individually and, therefore, the total numbers of the three types of organisms were three times as great as when each culture was added individually. The

justification for this method of comparison is that, since there were two variables, namely, the effect of numbers and effect of types of organisms, it was considered advisable to maintain equal numbers of each type in the mixture at the expense of increasing the total numbers of the three types of organisms.

The increase in the total yield of gas on the addition of cultures may be due to one or both of the following factors: (1) the digestion was more complete and further advanced with the cultures at the end of the experiment, *e.g.* if the solids were allowed to digest for a longer period they would have attained the same gas yield or (2) the asbestos cultures carried a sufficient amount of the respective organic substrates (calcium acetate,

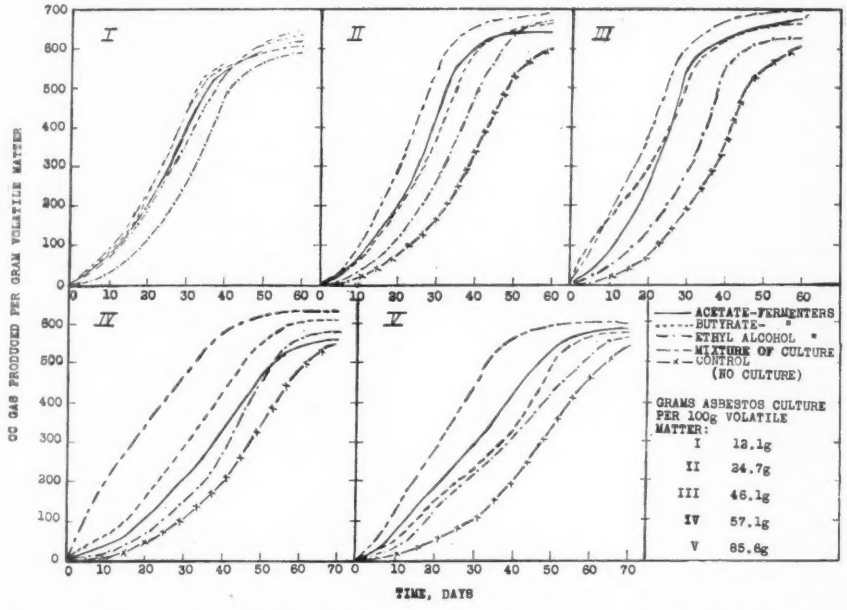

FIG. 1.—Effect on rate of digestion of adding varying amounts of asbestos cultures to batches of sewage solids limed to pH 7.2–7.6.

calcium butyrate and ethyl alcohol) as to yield increased amounts of gas. However, the increase in the yield of gas due to the addition of cultures was small in most cases (Table III).

In comparing the effect of increasing quantities of asbestos cultures on the acceleration of digestion it is necessary to bear in mind that the comparison cannot be made directly since different samples of fresh solids were used. Table IV, which gives the digestion time (calculated on the basis of 90 per cent of the gas production), should be examined with this in mind. It is safer to compare the effect of increasing amounts of cultures on the basis of the percentage reduction in time required for 90 per cent digestion, over the control. The maximum effect of increasing amounts of culture was reached with 46.1 grams of asbestos per 100 grams

TABLE III.—*Gas Yield * from Limed Solids Enriched with Asbestos Cultures of Methane Organisms*

Amounts of Asbestos Cultures Added† (Grams)	Control + Asbestos	Acetate-Fermenters	Butyrate-Fermenters	Ethyl Alcohol-Fermenters	Mixture of Cultures
	C.c.	C.c.	C.c.	C.c.	C.c.
12.1	585	620	630	640	610
24.7	595	645	660	670	680
46.1	610	670	670	645	715
57.1	475	555	600	570	615
85.6	475	550	550	515	585

* Per gram of volatile matter in 60 days.
† Per 100 grams of volatile matter of fresh solids.

TABLE IV.—*Time Required * and Per Cent Reduction of Time, for Digestion of Limed Solids When Enriched with Asbestos Cultures of Methane-producing Organisms*

Amount of Asbestos Cultures Added†	Control + Asbestos	Acetate-Fermenters		Butyrate-Fermenters		Ethyl Alcohol-Fermenters		Mixture of Cultures	
		Time	Reduct.	Time	Reduct.	Time	Reduct.	Time	Reduct.
Grams	Days	Days	%	Days	%	Days	%	Days	%
12.1	43	38	12	34	21	39	9	35	19
24.7	50	34	32	36	28	42	16	30	40
46.1	50	31	38	32	36	40	20	26	48
57.1	61	50	18	43	29	50	18	27	55
85.6	61	44	28	49	20	55	10	32	48

* On the basis of the time required to produce an amount of gas equal to 90 per cent of the total yield of gas from the control.
† Per 100 grams volatile matter.

of volatile matter. With higher quantities of asbestos there seemed to be a retardation of digestion, probably because a thick mat of asbestos and sludge was formed above the liquid level. The mixture of the three types of organisms gave a greater reduction in digestion time than each of them individually. When 57.1 grams of asbestos culture was added to 100 grams of volatile matter of fresh solids, the mixture gave the most rapid digestion, with a reduction of 55 per cent in digestion time.

The stimulation in the rate of digestion, however, is not so apparent from the above method of presentation because most of the acceleration due to the addition of cultures took place initially and on the basis of 90 per cent digestion these differences were considerably effaced. Therefore, the gas yields for each digesting solids mixture were calculated for 10, 20, 30 and 40 day periods. The gas yields from solids receiving a mixture of the three organisms were subtracted from their respective controls (limed solids without cultures) and the results are presented as percentage increases over the control, with different amounts of culture at different periods of digestion (Fig. 2). It is apparent that the stimulating effect of

the addition of cultures was greatest during the first ten days of digestion and decreased thereafter with each succeeding 10 day period. For each period the optimum amount of culture added was 171 grams of asbestos,

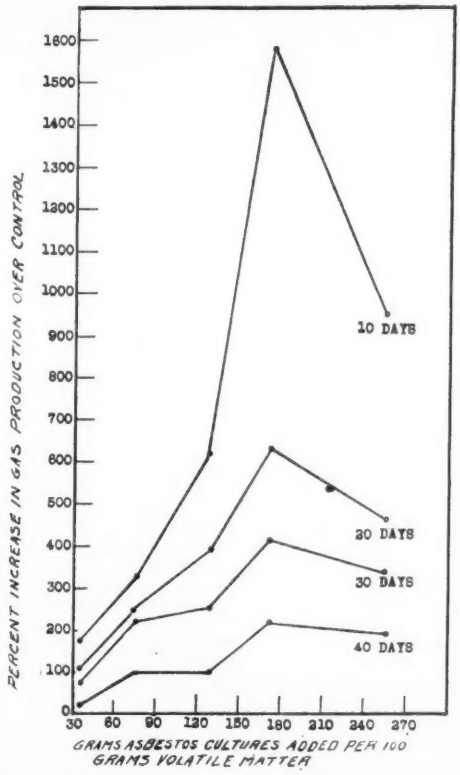

FIG. 2.—Percentage increase in gas production over the control with varying amounts of asbestos cultures of the three methane-producing cultures at different periods in the digestion process.

the increase being not so great with 256 grams (on the basis of 100 grams of volatile matter in the fresh solids). Gas production with 171 grams of cultures was 15 times as high as the control during the first 10 day period.

Septic Solids.—Two experiments were run with septic solids. In the first, fresh solids containing 4.5 per cent solids and 71.0 per cent volatile matter were allowed to become septic for a period of ten days. At the end of this period the solids were buffered with the following salts (per liter of fresh solids):

2.5g. NH_4HCO_3
1.5g. $(NH_4)_2CO_3$
1.5g. K_2HPO_4.

There were added 19.3 grams of asbestos cultures of methane organisms to the different portions (on the basis of 100 grams of volatile matter).

The difference between this and the previous experiments is that during the period of septicization prior to the addition of cultures no attempt was made to regulate the pH value but instead the pH value was adjusted after a period of acid digestion. In the second place, instead of using lime, a mixture of buffer salts were used to regulate the pH value. These salts actually prevented the pH value from dropping below 7.0 in subsequent digestion.

For the second part of the experiment, fresh solids containing 4.6 per cent solids and 64 per cent volatile matter were allowed to become septic without any attempt to correct the pH value during this period. Then, instead of using buffer salts as above, sterile supernatant liquor from digested sludge was used to regulate the pH value. The ratio of septic solids to sludge liquor used was 1.3 : 1 on a volumetric basis. Portions of these mixtures were then inoculated with asbestos cultures of methane-producing organisms in the ratio of 30.3 and 56.7 grams per 100 grams of volatile matter in the fresh solids. The gas production values from these various mixtures are given in Fig. 3.

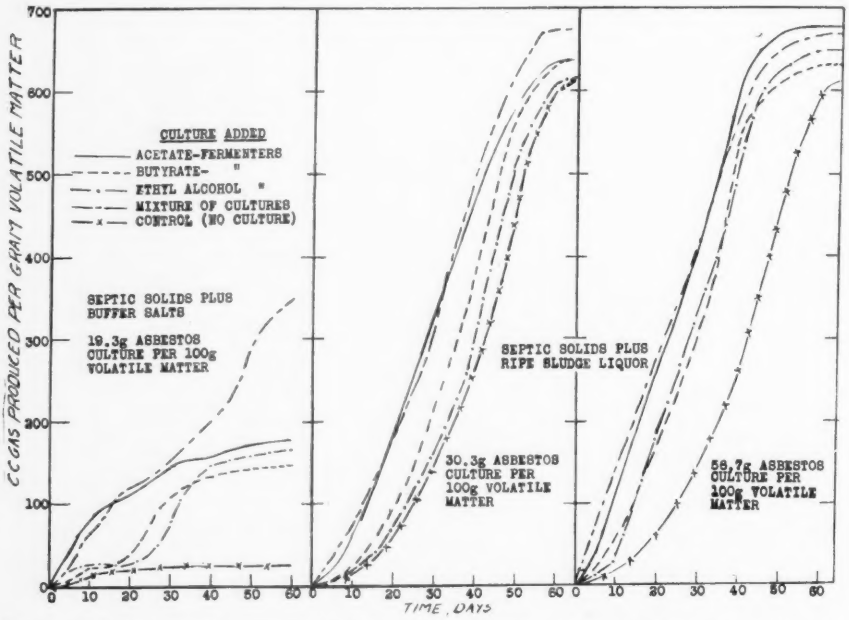
CC GAS PRODUCED PER GRAM VOLATILE MATTER
CULTURE ADDED
ACETATE-FERMENTERS
BUTYRATE- "
ETHYL ALCOHOL "
MIXTURE OF CULTURES
CONTROL (NO CULTURE)
SEPTIC SOLIDS PLUS BUFFER SALTS
19.3g ASBESTOS CULTURE PER 100g VOLATILE MATTER
SEPTIC SOLIDS PLUS RIPE SLUDGE LIQUOR
30.3g ASBESTOS CULTURE PER 100g VOLATILE MATTER
56.7g ASBESTOS CULTURE PER 100g VOLATILE MATTER
TIME, DAYS

FIG. 3.—Effect on rate of digestion of adding varying amounts of asbestos cultures to septic solid buffered initially with salts and ripe sludge liquor.

The septic solids with buffer salts did not digest satisfactorily during the 60 day period. When cultures were added to these solids considerable improvement in gas production was obtained, although gas production was not complete in any of the mixtures within 60 days. The mixture of cultures, added to the septic buffered solids, produced the greatest amount of gas (450 c.c. in 100 days) while the other cultures gave around 150 c.c. of gas in the same period. The control produced only 25 c.c. of gas.

When sterile ripe sludge liquor was added to the septic solids digestion proceeded rapidly. The addition of asbestos cultures to these mixtures showed considerable stimulation in gas production. The rate of gas production was higher with the higher amounts of asbestos cultures added. The mixture of cultures and the acetate cultures gave the greatest increase in the rate of gas production. The time required for 90 per cent of the total gas production and the percentage reduction of time of digestion of septic solids buffered with sterile sludge liquor, with varying amounts of asbestos-methane cultures, are given in Table V. It will be seen that the

TABLE V.—*Time Required * and Per Cent Reduction of Time for Digestion of Septic Solids Buffered with Ripe Sludge Liquor*

Amount of Asbestos in Cultures†	Control + Asbestos	Acetate-Fermenters		Butyrate-Fermenters		Ethyl Alcohol-Fermenters		Mixture of Cultures	
		Time	Reduct.	Time	Reduct.	Time	Reduct.	Time	Reduct.
Grams	Days	Days	%	Days	%	Days	%	Days	%
30.3	57	47	18	50	12	53	7	43	24
56.7	57	38	33	43	24	43	24	39	31

* Based on 90 per cent of gas yield from control.

† Per 100 grams of volatile matter.

percentage reduction in time due to the addition of equivalent amounts of asbestos cultures is not so great as it was when the cultures were added to limed solids. This may have been due to inherent differences in the original solids.

Fresh Solids.—In the following experiment buffer salts were added to the fresh solids without a previous period of septicization and the mixture was inoculated with asbestos cultures (0.62 gram asbestos cultures per 100 c.c. of fresh solids or 21.2 grams per 100 grams of volatile matter). The results are given in Fig. 4. Gasification of solids thus treated was slow, similar to the values obtained when buffer salts were used after a period of preliminary septicization. The addition of asbestos cultures increased the rate of gasification but even after 100 days less than 400 c.c. of gas was produced per gram of volatile matter from the most rapidly digesting mixture. The control during a similar period produced only 100 c.c. of gas.

DISCUSSION

It was shown in the second part of this series of papers that methane-producing organisms were present in fresh solids, but not in as high numbers as in rapidly gasifying ripe sludge. The objective in this investigation was, therefore, to augment the numbers of methane-producing organisms in fresh solids artificially by the addition of cultures, and thus to perform digestion in the absence of ripe sludge. It was recognized, however, that without making the environmental conditions favorable the mere introduction of enriched cultures would be of no avail. It has been previously shown [3] that ripe sludge has two functions (1) inoculation, (2)

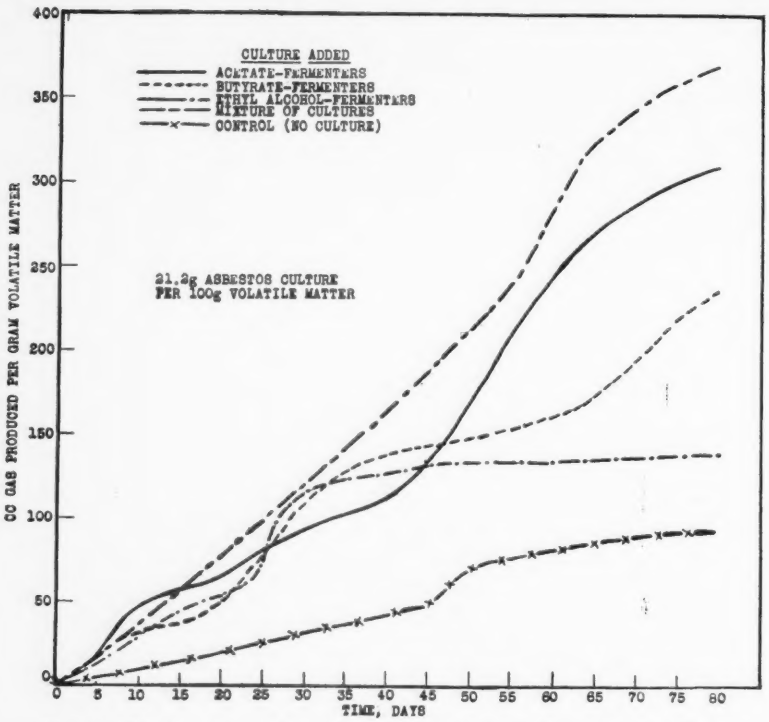

FIG. 4.—Effect on rate of digestion of adding asbestos cultures to fresh solids.

buffering. Thus it was essential to regulate the pH value by some other means if favorable results with the addition of cultures was to be expected. The pH regulation, therefore, was successfully accomplished by the addition of lime or buffer salts

Another factor that had to be considered was that the methane organisms cannot use complex organic materials such as fats, celluloses and proteins directly. These materials have to be hydrolyzed into simpler compounds such as acetate, butyrate and ethyl alcohol before the methane organisms can utilize them. In other words, the fresh solids had to be liquefied by another group of organisms. No attempt was made to bring about this phase of the digestion by adding cultures of liquefying organisms. It was assumed that these organisms were present in the fresh solids in sufficient numbers so that methane production would not be limited by this factor if inoculation with methane-producing organisms and pH regulation had been properly made. This assumption may not be entirely correct, but future work with the liquefaction phase will demonstrate the validity of the assumption. Liquefaction may be induced either prior to the addition of methane-producing cultures, by allowing the fresh solids to digest with or without pH regulation, or liquefaction may be allowed to progress simultaneously with gasification. Both these methods were used. If liquefaction proceeds more slowly than

gasification the addition of cultures to the fresh solids will not show the maximum stimulating effect, because the organisms introduced will be limited in their activity by the lack of proper food. By allowing a period of digestion prior to the addition of the cultures it was assumed that food for the methane-producing organisms would accumulate so that when these organisms were added they would begin to gasify immediately. However, when the fresh solids are allowed to become septic after the initial rapid acid production even liquefaction is retarded. It has been shown [4] that the addition of lime increases the production of volatile acids; therefore, lime was added during the initial period to induce liquefaction before the addition of cultures.

A final factor which had to be taken into account was the concentration of the methane-producing cultures. It would have been of little value to add the organisms from the liquid medium. Although the organisms in the liquid medium attain high numbers, so much volume would have to be added to approach the numbers present in the ripe sludge that it would result in considerable waste of tank capacity. For this reason the organisms were grown in the presence of asbestos in the culture medium. The liquid after each growth period was decanted and fresh medium added. A maximum concentration of the organisms on asbestos took place after the third transfer beyond which no further increase took place. Asbestos cultures prepared in this way, after decanting the supernatant, were added to the fresh solids in the different experiments. The organisms capable of developing on acetate, butyrate and ethyl alcohol substrate were enriched and added individually to the solids. In addition a combination of the three cultures was used.

The results show that the addition of cultures thus prepared resulted invariably in greater rates of gas production. However, under certain conditions the stimulation was greater than at others. Some of the factors that affected this stimulation were as follows:

Type of Culture.—Generally speaking, the addition of alcohol-fermenting organisms resulted in the lowest stimulation in gas production. The reason for this is probably due to the fact that alcohol is not produced in large quantities by the liquefying organisms in fresh solids. On the other hand the addition of acetate-fermenting cultures gave the best stimulation of all the cultures added individually. It is known that acetic acid is one of the important volatile acids produced during liquefaction.[5] The mixtures of the three cultures added in combination gave, invariably, the highest rate of gas production. This might be due to the fact that three times as many organisms were added in combination or that each of the organisms added plays an important part in gasification, utilizing different compounds produced in liquefaction.

Quantity of Culture.—When increasing quantities of enriched asbestos cultures were added, up to a certain point, greater rates of gas production were obtained. Beyond a certain point, increasing quantities of asbestos resulted in a noticeable relative decrease in the rate of gas production. It was observed in these cases that all of the sludge rose to the top and formed a mat with the asbestos. This is due to the peculiar physical character of

asbestos; results with some other inert carrier not subject to the flotation effect of gas bubbles will be reported in a subsequent paper.

The additions of asbestos cultures might be expressed either on a volumetric or volatile matter basis. Both these methods of expression have been used. The quantities of asbestos cultures added varied from 0.38 to 2.5 grams per 100 c.c. of fresh solids; 0.38 gram of asbestos occupied a volume of 4.5 c.c. and 2.5 grams 30 c.c. when added in a wet state. The amount of culture which gave the optimum results was about 1.3 to 1.6 grams for 100 c.c. sludge occupying a volume of 12 and 15 c.c. respectively. On a volumetric basis the ratio of asbestos culture to sludge was approximately 1 : 6.5. There is no reason why a more suitable inert carrier cannot be developed which would not occupy so much space when wet. On a solid matter basis the amount of asbestos culture added varied from 12.1 grams to 85.6 grams per 100 grams. The amount of culture which gave the best results varied from 46.1 to 57.1 grams on this basis. Since the usual fresh solids to ripe sludge ratio is 1 : 1 on the basis of solid matter, the addition of the asbestos cultures on this basis compared favorably with the ripe sludge inoculation. It should be remembered that these relationships are based on the addition of individual cultures and that when the mixture of cultures was added the quantities were increased threefold.

In Table VI a comparison of the numbers of methane organisms added

TABLE VI.—*Comparison of Methane-producing Organisms in Two Ripe Sludges and an Enriched Culture (after Three Transfers)*

	Methane-producing Organisms in Millions (per Gram Solids)		
	R.S. at Peak of Gasification	R.S. Past Peak of Gasification	Enrichment Cultures
Acetate-fermenters	950	12	933
Butyrate-fermenters	252	5.4	660
Ethyl alcohol-fermenters	4,600	121	33,000

in the enriched asbestos cultures and by ripe sludge is made. The values of ripe sludge are taken from Part II, Table II of this series. The numbers in the asbestos cultures are taken from Table I of the present paper. They are both expressed on the basis of grams of solids. The numbers of the various types of methane-producing organisms in the asbestos cultures are considerably higher than those present in ripe sludge even at the peak of gasification. Since the quantities of asbestos cultures added were similar to the quantities of ripe sludge on volatile matter basis it is evident that the asbestos cultures provided at least as many organisms as the ripe sludge ordinarily used.

Treatment of Solids.—The addition of the cultures to properly seeded fresh solids and ripe sludge mixtures gave no improvement in the rate of gas production. This is what would be expected since the ripe sludge furnished sufficient organisms and the addition of greater numbers would not result in greater activity with the amount of food available. The

best results were obtained when the fresh solids were limed for a period of ten days prior to the addition of cultures. This may have been due to the production of greater amounts of volatile acids, which are nutrients for the methane-producing bacteria, or the removal of deleterious compounds during the liming stage. At pH 7.0 to 7.6 the cultures added found sufficient amounts of food and the proper conditions with regard to reaction and environment.

Allowing the solids to become septic under acid conditions and then regulating the pH with buffer salts and inoculating the solids with cultures was not a satisfactory method of treating the solids, because the rate of gas production under these conditions was slow. This difficulty probably arose from the production of certain deleterious substances during the acid digestion period, which could not be overcome by the addition of buffer salts. One of us has already reported [3] favorable digestion when these same buffer salts were used to regulate the pH value of digesting fresh solids. Furthermore, although the regulation of the pH value with sterile ripe sludge liquor, after a period of acid digestion of fresh solids, resulted in an improvement over the buffer salts it did not give as high a rate of gasification as when the solids were limed continuously during the preliminary period of digestion. It would appear, therefore, that acid digestion of fresh solids resulted in the production of certain deleterious substances which retarded the methane fermentation. The evidence in the literature [6, 7] regarding the effect of septic solids on digestion is conflicting. Experiments to be reported subsequently will attempt to determine more definitely the reason for the retardation of methane fermentation when septic solids are used.

Gas Yield.—The results show that the addition of enriched asbestos cultures resulted invariably in somewhat higher gas yields. As pointed out, this might be due to (1) the stimulation of digestion by the addition of culture (2) the addition of small amounts of organic substrates with the asbestos cultures. It is true that asbestos cultures contributed some organic substrate when added to the solids because of the liquid absorbed by the asbestos. It is difficult to estimate the amount of the organic substrate contributed by this source. The volume occupied and the maximum amount of the organic salts (initial concentration of the medium) contributed by the various amounts of asbestos cultures added were as follows:

Asbestos Culture Added Gms.	Volume C.c.	Maximum Organic Substrate Gms. (C.c. Ethyl Alcohol)
0.38	30	0.3
0.72	50	0.5
1.36	70	0.7
1.66	100	1.0
2.50	200	2.0

The amount of the salts remaining after the growth of the methane organisms in these substrates is not known. When different quantities of calcium acetate and butyrate were added to ripe sludge the gas production

was slightly less than in the control for the first 5 to 8 days (see Fig. 5); thereafter the gas production from the control decreased while those with the organic salts increased. The more salts added the greater was the increase. It seems probable that the increased total yield of gas was due to the organic salts added with the enriched asbestos cultures, but that

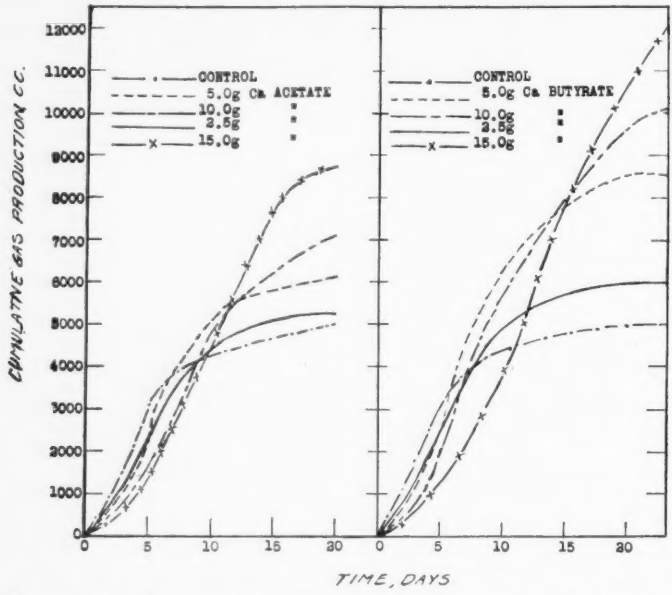

FIG. 5.—Gas production from varying amounts of calcium acetate and butyrate added to a ripe sludge.

the added salts were probably not the cause of increased gas production in the inoculated solids initially, this being solely due to the addition of the organisms.

Degree of Stimulation.—As has been indicated above, the degree of stimulation is dependent on the kind of culture added and the quantity and type of treatment of solids. Asbestos cultures of acetate-fermenters gave a maximum reduction of 38 per cent in time required to produce 90 per cent of the gas, when added in the ratio of 46.1 grams per 100 grams of solids. The mixture of the cultures gave a maximum of 55 per cent reduction. However, these values refer to the stage when gasification was nearly complete. The initial stimulation is well illustrated in Fig. 2, when, during the first 10-day period, the addition of mixed cultures resulted in as high as a 14 to 15-fold increase in gas production over the control. Thus the maximum effect of the addition of cultures is exerted during the initial periods of digestion. The methane-producing organisms at this stage of the digestion of fresh solids are limited in numbers; therefore, the artificial addition of large numbers makes its effect felt rapidly. However, as digestion proceeds the numbers of methane organisms originally present in fresh solids greatly increase, so that the presence of the artificially introduced organisms does not exert a great deal of influence at this stage.

Application.—The application of the utilization of cultures of methane-producing organisms will be especially valuable when ripe sludge is not available for starting a new tank. The working-in period with the use of enriched cultures would be greatly reduced. It would also be valuable when digestion is upset and the organisms in the ripe sludge are killed due to an accidental lowering of the pH value or the introduction of some toxic waste material. It would be necessary, however, to correct these disturbing influences adequately prior to the addition of cultures.

Summary and Conclusions

1. A study was made on the effect of the addition of three different cultures of methane-producing organisms on asbestos to digesting sludges.

2. The effect of repeated enrichment of the culture on the numbers of organisms was determined and the population level per gram of asbestos was not found to change materially after the third subculture. The numbers of organisms for inoculation can be varied by using different quantities of asbestos.

3. The addition of cultures to seeded solids did not alter the rate of gas production.

4. The digestion of limed solids was accelerated by the addition of cultures. The extent of acceleration depended on the type and amount of asbestos culture added. With 57.1 grams of asbestos culture of each of the three types of organisms, added in combination to 100 grams of volatile matter, a 55 per cent reduction in the total digestion time was brought about. The rate of acceleration was much more pronounced with shorter periods of digestion. Larger quantities of asbestos cultures retarded digestion due to the formation of a mat of asbestos and sludge on the surface of the liquid.

5. The ethyl alcohol-fermenting organisms caused the smallest acceleration of gas production, the acetate- and butyrate-fermenting organisms the highest when used individually. When a combination of the three was added the best results were obtained.

6. Septicization of solids under acid conditions followed by adjustment of pH with buffer salts and inoculation with enriched asbestos cultures resulted in a slower digestion than when the solids were limed during the initial period. However, the addition of cultures considerably increased the rate of gas production over the control.

7. Septicization of solids under acid conditions followed by adjustment of pH with sterile ripe sludge liquor and addition of enriched asbestos culture improved the digestion over similarly treated solids buffered with buffer salts, but the sludge did not gasify so rapidly as limed solids inoculated in a similar way.

8. Slightly higher yields of gas were produced when asbestos cultures were added to fresh solids, probably due to the nutrients added with the asbestos.

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GROWTH PROMOTING SUBSTANCES IN SEWAGE AND SLUDGE *

III. VITAMIN C, CAROTENE, AMINO ACIDS, FATTY ACIDS, AND NAPHTHYL COMPOUNDS

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Publications reporting work on growth promoting substances appear almost daily. Considerable work on the ability of certain compounds to stimulate the growth of plants has been published since the first paper [1] in this series was presented, and another review would be necessary to bring the material up-to-date. However, the additional literature confirms and extends previous work. Various compounds capable of growth stimulation are highly complex, produced in nature by the decomposition of organic matter. For this reason it was believed that sewage and sludge, containing domestic wastes products and frequently wastes from industrial enterprises, should contain various growth promoting substances thus far identified. The various sewage and sludge treatment processes conceivably would affect the quantities and types of growth promoting substances present in the finished products.

In a second paper [2] the presence of indole and skatole was shown in various sewages, sludges and effluents. These substances have a pronounced effect on certain growth promoting phenomena of plants and crops, especially stimulation of root growth. In the present paper results are presented dealing with other substances, which have various growth promoting effects.

Experimental

Sampling.—The liquid samples were taken and used for the various analyses without further treatment. To facilitate sampling before analysis, the various sludges were heat dried at 100° C. and pulverized. Since many of the complex organic substances are partially destroyed by high temperature, it is possible that drying at 100° C. may have reduced to some extent the quantities of growth promoting substances present, but since all sludges were treated alike the relative relations should remain fairly constant.

Analyses.—The various analyses used were chosen from an extensive study of the literature available, but are not necessarily the best possible. Since the studies were limited to determine whether or not the various growth promoting substances were present, the results are in part expressed in relative values rather than exact quantities. The quantities undoubtedly will vary with the type of sewage and sludge as well as with the treatment processes employed.

* Journal Series Paper, New Jersey Agricultural Experiment Station, New Brunswick, N. J Dept. Water and Sewage Research.

Ascorbic Acid (Vitamin C).—This substance was determined according to the method of Roe.[3] The test consists, essentially, of converting ascorbic acid, after removing all fermentable interfering sugars, to furfural and determining this substance colorimetrically with alcoholic aniline acetate. In no instance was the color developed of sufficient intensity to permit quantitative comparison with prepared standards. Various shades of a pinkish-orange tinge could be observed and the results presented indicate whether a greater or lesser amount of ascorbic acid was to be found.

The amount of sewage or liquid sample used in the analysis was 20 c.c., the dried, sludge samples were prepared by extracting 4 grams with 20 c.c. of warm, distilled water. The solids were removed by centrifuging and the liquid portion, made up to 20 c.c., was used for the analysis.

Carotene.—Carotene was determined on the liquid samples by means of the Carr-Price antimony trichloride test as modified by Rosenthal.[4] The sludges and solids were analyzed according to the procedure of Guilbert, which is an extraction method in which the yellow carotene is isolated in solution and compared to color standards. The purified extract could also be tested by the Carr-Price reaction. Four gram samples of dried sludge were used and 10 c.c. samples of liquid.

Results are based on the intensity of the color obtained. The method is not sensitive enough to detect extreme small quantities.

Tyrosine and Tryptophane.—Analyses were made for both the free and combined amino acids according to the methods of Lugg.[5, 6] To determine combined amino acids the material was first hydrolyzed with alkali, the solids were removed, and tryptophane was precipitated with an acid-mercuric solution. Tyrosine remains in solution. When either of the amino acids are present the addition of sodium nitrite gives a red colored solution. It was not necessary to subject the materials to hydrolysis when the free amino acids were determined. Interfering halides, phenols and indoles were removed by extractions with toluene and ether.

Two-gram portions of solids and 20 c.c. portions of liquid samples were used in the determinations.

Phenyl Derivatives.—Known methods do not permit an easy identification of these compounds. Since they are easily converted to benzoic acid by mild oxidation, the presence of this substance was taken as evidence of the presence of the phenyl radical in the sewage or sludge analyzed.

The sewages and effluents were subjected to oxidation immediately by dichromate and tested for the presence of benzoic acid as described and then extracted in a Soxhlet apparatus with ethyl alcohol. The alcohol was removed by evaporation and the residue oxidized with dichromate. The test for benzoic acid consisted of treating the salt with a neutral solution of ferric chloride to form ferric benzoate, a reddish precipitate. Other substances, such as phenol, give color compounds with ferric chloride, but when the reddish precipitate is washed with cold water it can be easily identified. Controls were run on the sewages and sludges prior to oxidation in order to detect benzoic acid.

Twenty cubic centimeters of liquid sample and three grams of dried sludge were used for the tests.

Volatile Fatty Acids.—The method used was that of Rawn, Banta and Pomeroy [7] in which the acid distillate from 200 c.c. of sewage or sludge liquor is extracted three successive times with ether and the amounts of acid present are calculated from the fraction of acid removed from the aqueous solution in each extraction.

α-Naphthyl Compounds.—These substances could be determined by mild oxidation to α-naphthol, which is easily identified.

Results

In comparing the various results obtained it should be kept in mind that the method of presentation shows the relative amount of a single substance present and can not be translated to the presence of equal quantities of other substances, although the mode of expression is the same. For instance, a 4+ for ascorbic acid does not mean that this substance was present in the same concentration as a 4+ for carotene. It means that a more intense color reaction was obtained than for a 3+ ascorbic acid. The exact quantities of carotene may have been materially greater.

Ascorbic Acid.—Experiments with Vitamin C have shown that the dry weight of plants may be increased by 35 to 75 per cent when concentrations of 1 part in 10,000 are used. Certain plants are stimulated materially, causing increase in length of shoots. Results on the presence of ascorbic acid in various sludges and sewage and effluents (Table I) indicate that

Table I.—*Various Growth Promoting Substances in Sewage and Sludge*

Material Analyzed	Ascorbic Acid	Carotene	Tryptophane		Tyrosine		Phenyl Compounds*	Naphthyl Compounds†
			Free	Combined	Free	Combined		
Fresh solids	++++	+++	++++	++++	++++	++++	++++	−
Digested spray-dried sludge	+++	++++	++	+++	++	++	+	−
Vacuum dried sludge	++++	++	+	++	+	++	++	−
Activated sludge	++++	+	++	+++	++	+++	++	−
Raw sewage	+	−	+++	++++	+++	++++	++++	−
Primary settling effluent	−	−	++++	++++	++++	++++	+++	−
Trickling filter influent	−	−	+++	+++	++++	+++	+++	−
Trickling filter effluent	+	−	+	+	−◦	−	−	−
Final oxidation effluent	−	−	+	−	−	−	−	−

* Determined as benzoic acid.

† Determined as α-naphthal.

fresh solids and wet activated sludge contain considerable quantities. When the sludge is chemically treated with iron salts for dewatering there appears to be no reduction, but when the sludge is digested and spray-dried (heated) there is some reduction. It is of interest that even this drastic method of sludge treatment (digestion, treatment with alum and spraying in hot air) does not destroy the ascorbic acid. The content of ascorbic acid in raw sewage appeared to be small, and it could not be detected in settled sewage. This indicates that the substance is retained by the settling sludge. The settled sewage obtained from another source did not contain ascorbic acid, but the effluent from a trickling filter contained as much as the raw sewage, while the settled trickling filter effluent showed the same results as the settling tank effluents. This again seems to indicate that the substance is associated with the suspended material.

Aeration in an activated sludge plant or trickling filter does not seem to destroy the vitamin.

Carotene.—Rootlets form more rapidly when minute quantities of carotene are present. At least two pigments of the carotenoid type are associated with the green pigment in the purple and sulfur bacteria but absent in the green bacteria. Carotene is present in fresh solids and digested sludge and persists after heat drying. Addition of chemicals for dewatering and activation appears to reduce the relative quantities. In raw or settled sewage carotene could not be detected.

Tryptophane.—Through the bacterial breakdown of the amino acid, tryptophane, indole is produced. In the putrefaction of proteins indole and indoleacetic acid have been repeatedly identified. The precursor of indole is probably tryptophane. Indole and β-indoleacetic acid have been produced under certain conditions from tryptophane under aerobic conditions by *B. coli.* Under anaerobic conditions β-indolepropionic acid has been produced both by *B. coli* and by Rauschbrand's bacillus. The products formed by the bacterial breakdown of tryptophane vary according to the organisms present and the conditions of the medium.

The various tryptophane breakdown products affect root growth, and produce earlier rooting, increased numbers of roots, and retardation of non-dormant buds. They also inhibit the growth of fungi and molds attached to roots, shoots and germinating seeds, stimulate germination of a number of seeds, and cause more rapid fruit development.

Free and combined tryptophane is present to the greatest extent in fresh solids, is reduced by digestion, chemical treatment or aeration. Considerable amounts are present in raw sewage and remain in the sewage after settling, but upon oxidation of the sewage disappear.

Tyrosine.—The amino acid tyrosine is broken down under anaerobic conditions to a fatty acid and ammonia. A number of bacteria are able to decarboxylate tyrosine. It may be oxidized by bacterial action in the presence of oxygen. Certain molds are able to convert tyrosine into growth substances. These molds grow rapidly on the surface of sludge or penetrate into the sludge when conditions of air and heat are favorable. They may have considerable effect on composting processes.

Free and combined tyrosine is present in fresh solids and activated sludge to a less extent; the relative quantities appear to be reduced by heat drying and chemical treatment. Settling of sewage does not affect the quantities present in sewage, but oxidation decreases the amounts present in the liquid. This may be caused by removal of suspended material and partially to oxidation of the substances present in the liquor. The fact that fresh activated sludge contains less than fresh solids seems to point in the direction that oxidation is of some importance in the reduction.

Phenyl Compounds.—Phenyl compounds are produced in the putrefaction of meat by certain anaerobic bacteria such as *B. proteus* and *B. pyocyaneus.* Several of the compounds can also be oxidized by bacterial action. The various phenyl compounds have been reported to possess growth promoting properties, especially inducing bending, swelling and rooting and producing rapidly new cells and buds.

The phenyl compounds grouped in Table I would include such growth promoting substances as phenylacetic and phenylpropionic acids, benzoyl oxide, benzoyl peroxide and phenylalanine. Fresh solids and raw sewage contain the largest amounts of phenyl compounds. Heat and oxidation reduces them greatly, so that the quantities in fresh activated sludge are materially less and may be absent in the oxidized liquid.

α-Naphthyl Compounds.—These compounds include the α-naphthyl-alene-acetic series which have been found to be the most potent growth promotors thus far discovered. The various domestic sewages and sludges tested did not contain these compounds in measurable quantities. It is possible that sewages or wastes from other than domestic sources contain these compounds.

Volatile Acids.—Various growth promoting substances are known to be effective in combination with organic acids such as indole-acetic, indole-propionic, indole-butyric, phenyl-acetic, phenyl-propionic acids, etc. In a study of growth promoting substances produced or present in raw or oxidized sewage, decomposing and variously treated sludges it is of some consequence to know the quantities of the various organic acids present under different conditions. The results given in Table II show the quanti-

TABLE II.—*Volatile Acids*

Material Analyzed	Formic	Acetic	Propionic	Butyric	Valeric
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
Fresh solids	0	1270	42	112	26
Septic solids	0	2150	1150	400	0
Digested spray-dried	0	5	16	0	0
Chemically treated, vacuum dried	0	5	7.5	1.5	0
Raw sewage	0	36	8	17	0
Primary settling effluent	0	37	9	2	0
Trickling filter effluent	0	0	0	0	0
Final effluent	0	0	0	0	0

ties of the five lower fatty acids which were determined in the acid distillates of the sewages and sludges. Valeric acid was found to be present in small quantities in fresh solids but not in septic, digested or activated sludges. Acetic, propionic and butyric acids were the main volatile fatty acids, which increased greatly on septicization, but decreased greatly or were entirely destroyed upon heat drying or drastic chemical treatment. The same volatile acids were present in raw and settled sewage, but disappeared, or the quantities became so small that the method used was not sensitive enough to detect their presence, upon oxidation.

The relative relationships of the various volatile acids are better shown in percentages (Table III). The fresh solids and raw sewage contained markedly higher percentages of acetic acid. On septicization of the sludge relatively more propionic acid is formed, while this same acid appears to be more resistant to heat drying and chemical treatment. Heat drying and chemical treatment reduces materially the relatively small amounts of

TABLE III.—*Relation of Volatile Acids*

Material	Total	Acetic	Propionic	Butyric	Valeric
	P.p.m.	%	%	%	%
Fresh solids	1450	87	3	8	2
Septic solids	3700	58	31	11	0
Spray dried	21	24	76	0	0
Vacuum dried	14	42	55	3	0
Raw sewage	61	60	12	28	0
Settled sewage	49	78	18	4	0

butyric acid. On settling the volatile acid constituents decrease and the butyric acid begins to disappear.

DISCUSSION

Fresh solids appear to be an excellent source of the various growth promoting substances, invariably showing the presence of relatively high concentrations. Sewage solids in the process of septicization or during digestion increase markedly in growth promoting substances as well as in indole and skatole, as previously shown. This is to be expected because these substances are degradation products of complex materials produced by bacterial action. As indicated before several of the substances may be produced under aerobic as well as under anaerobic conditions. As a rule the substances formed under aerobic conditions are retained in the sludge in smaller quantities than those formed under anaerobic conditions. Since these organic growth promoting substances are subject to further decomposition and oxidation we would expect to find that oxidized effluents contain very small quantities or none at all. It could also be expected that heat drying would reduce or destroy these intermediate products. In the digestion processes certain complex organic materials are rapidly broken down at the beginning, the intermediate products formed are reduced further to simpler compounds, but sufficient organic matter remains, even after the sludge is ready for disposal, to supply a definite amount of the various intermediate products. However, the type of intermediate product formed or remaining shifts relatively from one degradation product to another. This is clearly shown when the volatile organic acids are determined. Incidentally, their determinations throw considerable light on the digestion processes, the agencies involved and the intermediate products formed.

Sewages are relatively poor in ascorbic acid and carotene as compared with the different types of sludges. This, together with the fact that septic solids contain more of the growth promoting substances, indicates that the solids received at the plant have not been decomposed far enough and that these compounds are retained by the sludge. On the other hand raw and settled sewage and supernatant liquors are relatively rich in tryptophane, tyrosine and phenyl compounds. Tryptophane, which is the source of indole and probably skatole, appears to be formed at an early stage in the decomposition processes. It is slightly soluble in cold and

very soluble in hot water, so that it would remain in the sewage after settling.

When dealing with substances such as ascorbic acid, carotene, tyrosine and tryptophane, where direct methods of determination are available, it becomes easier to reach conclusions as to the presence of these growth promoting substances in sewage and sludges. For the present it was considered sufficient to indicate the presence of these growth promoting substances, rather than to undertake extensive qualitative analyses. The presence and production of these same substances in other decomposing materials such as garbage, various organic wastes and waste products can be postulated and some work has been done along these lines. Considerable work has also been done on the extraction of these and other growth promoting substances. A part of this work will be reported in a following paper.

The identification of such growth stimulating compounds as α-phenylacetic and α-naphthaleneacetic acids or their derivitives in sewages and sludges is more difficult, especially if they exist in extreme small quantities. Identification of definite portions of these compounds such as the naphthyl or phenyl radical is valuable, but we cannot be certain that the compounds from which these radicals have arisen are necessarily growth promoting substances. We may assume that if the phenyl or naphthyl radical is present, as well as the acid side chains, the growth promoting substances were present in the desired form. Biological methods were used to determine more definitely the presence and value of the various growth promoting substances. Some results will be reported in a subsequent paper.

Septic solids were found to contain considerably more volatile acids than fresh solids. It is a well-known fact that these various organic acids tend to increase under natural digestion conditions and are either responsible for retardation of proper digestion or accumulate to such an extent that interference takes place with bacterial action in the further breakdown of these compounds. A series of experiments have been conducted to determine the effect of various intermediate breakdown products on the rate of sludge digestion. The results will be discussed in another paper. It is of interest that the digestion processes can be readily modified to produce various results.

Summary

Various sewages, sludges and effluents were analyzed for the growth promoting substances ascorbic acid (Vitamin C), carotene, tryptophane, tyrosine, phenyl and naphthyl compounds. Determinations were made of the volatile formic, acetic, propionic, butyric and valeric acids. The analyses of growth promoting substances were of a qualitative or semi-quantitative nature; the shortcomings of some methods are discussed. Fresh and septic solids were found to be the best sources of the substances tested for, with fresh activated sludge following. Digestion reduced the quantities, and heat drying or drastic chemical treatment of digested sludge reduced the amounts of substances. Carotene and ascorbic acid were relatively scarce in raw sewage, while the other substances were rela-

tively abundant. Oxidation of sewage liquors reduces or destroys the various growth promoting substances. The relative percentages of the various organic volatile acids change during digestion and the acids are destroyed by oxidation.

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ACTIVATED SLUDGE OXIDATIONS

III. FACTORS INVOLVED IN PROLONGING THE INITIAL HIGH RATE OF OXYGEN UTILIZATION BY ACTIVATED SLUDGE-SEWAGE MIXTURES

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It has been recognized for some time that when activated sludge and sewage are first mixed they use oxygen at a rather high rate and that the rate diminishes as the oxidation progresses. In 1935, Kessler and Nichols [1] reported on a study made of oxygen utilization by activated sludge in which they showed that the initial high rate of oxygen usage by activated sludge-sewage mixtures often persisted at fairly constant values for periods as long as one hour duration. They concluded from their work that the length of time which the maximum rate of oxidation lasted was in proportion to the strength or 5-day B.O.D. of the sewage.

Sawyer and Nichols [2] have shown that the character of the oxygen utilization rate curves produced by two different activated sludges when oxidizing the same sewage may be widely dissimilar. From those studies it was concluded that the oxygen utilization rate curves for activated sludge oxidations was of at least three distinct types. Two of these types involved maximum rates of oxygen usage which lasted for considerable periods of time. An attempt to correlate the data obtained on the basis of sewage strength, as measured by the 5-day B.O.D., was fruitless and, as a consequence, an investigation was started in an attempt to determine the factors responsible for the variations.

Methods and Sources of Materials

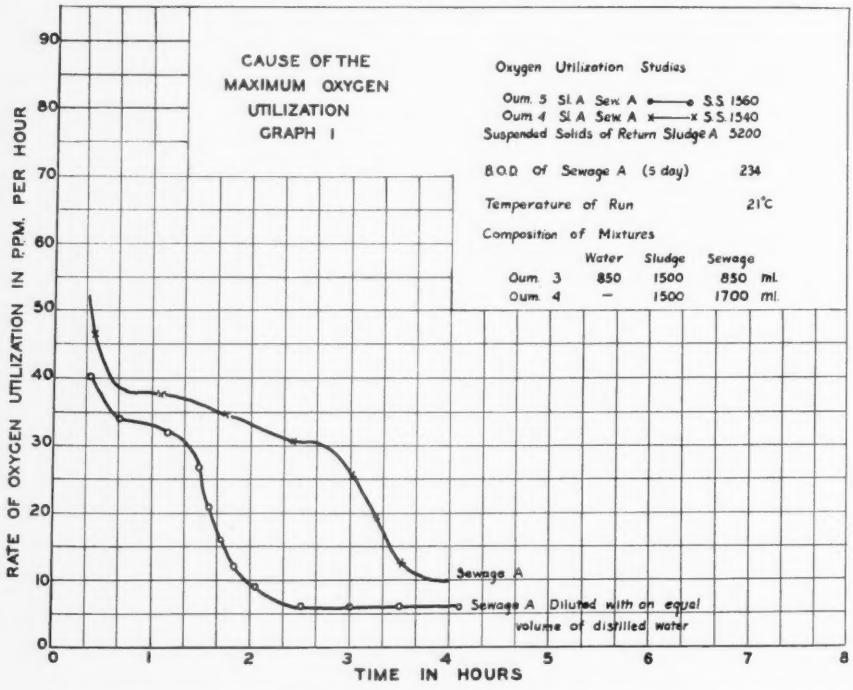
The character of the oxygen utilization rate curves produced by the various activated sludge-sewage mixtures was determined by means of the four Oxy-Utilometers previously described.[3] Other information of a chemical nature was obtained by procedures outlined in Standard Methods of Water Analysis (1936).

Activated sludges were obtained from two Wisconsin cities, A and C, and kept in good condition in the laboratory by feeding on sewage from City A. These cities were chosen as sources of sludge because of the markedly different oxidation curves given by the sludges when oxidizing the same sewage or substrate.[2]

Samples of sewage were obtained from an institution near City A, and from four different pumping stations and nine intercepting sewers in City A. In most cases the samples were of the "catch" variety and were collected between the hours of 8 and 10 A.M.

Experimental Results

The early work in this investigation was done with the aid of Sludge A, a sludge which normally gave prolonged high rates of oxygen utilization when treating Sewage A. The first step was to determine whether the sludge or the sewage was the important factor in producing the high rates which persisted for considerable lengths of time. To accomplish this, two identical portions of Sludge A were taken and one portion was mixed with full-strength sewage and the other with half-strength sewage (50 per cent sewage, 50 per cent distilled water). The oxygen utilization rate curves of the two mixtures were determined with the aid of the Oxy-Utilometers and the results are shown in Graph 1. From this graph it can be seen that the

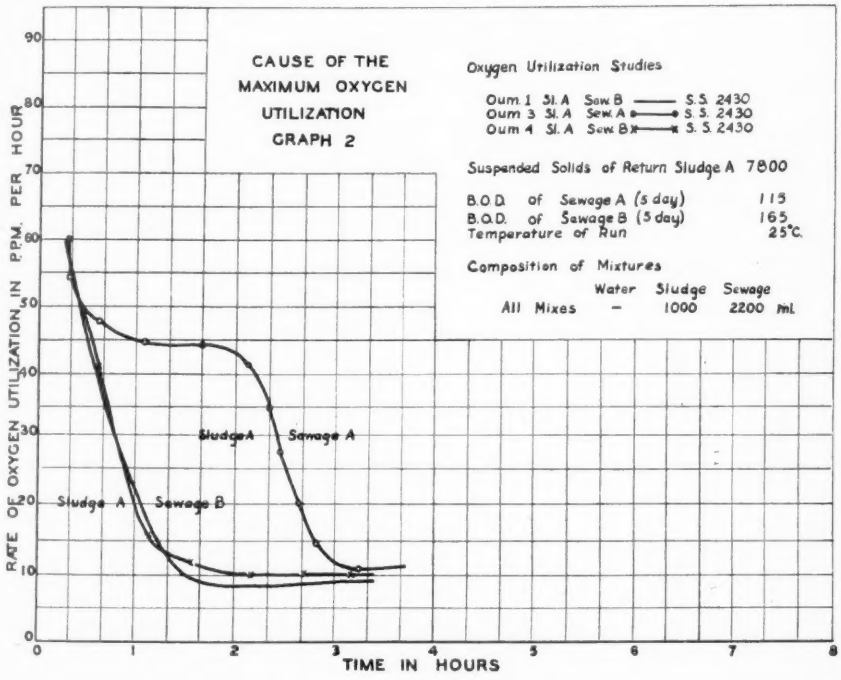

CAUSE OF THE MAXIMUM OXYGEN UTILIZATION GRAPH 1
Oxygen Utilization Studies
Oum. 3 Sl. A Sew. A S.S. 1560
Oum. 4 Sl. A Sew. A S.S. 1540
Suspended Solids of Return Sludge A 5200
B.O.D. Of Sewage A (5 day) 234
Temperature of Run 21°C
Composition of Mixtures
Water Sludge Sewage
Oum. 3 850 1500 850 ml.
Oum. 4 — 1500 1700 ml.
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS
Sewage A
Sewage A Diluted with an equal volume of distilled water

high rate of oxygen utilization lasted only approximately one-half as long with the diluted sewage as it did with the full-strength sewage. Since the amount and kind of sludge used in each case was the same, it was concluded that sewage was the important factor in prolonging the high rate of oxygen usage. In this particular study we note again that the sludge treating the sewage with the higher B.O.D. gave the higher rate of oxygen utilization, as has been previously pointed out.[2]

Similar studies made with filtered sewage as compared with raw sewage, and pre-aerated sewage (45 min.) as compared with raw sewage, demonstrated that the length of time during which the maximum rate of oxygen utilization persisted was not materially affected by either of these variables.

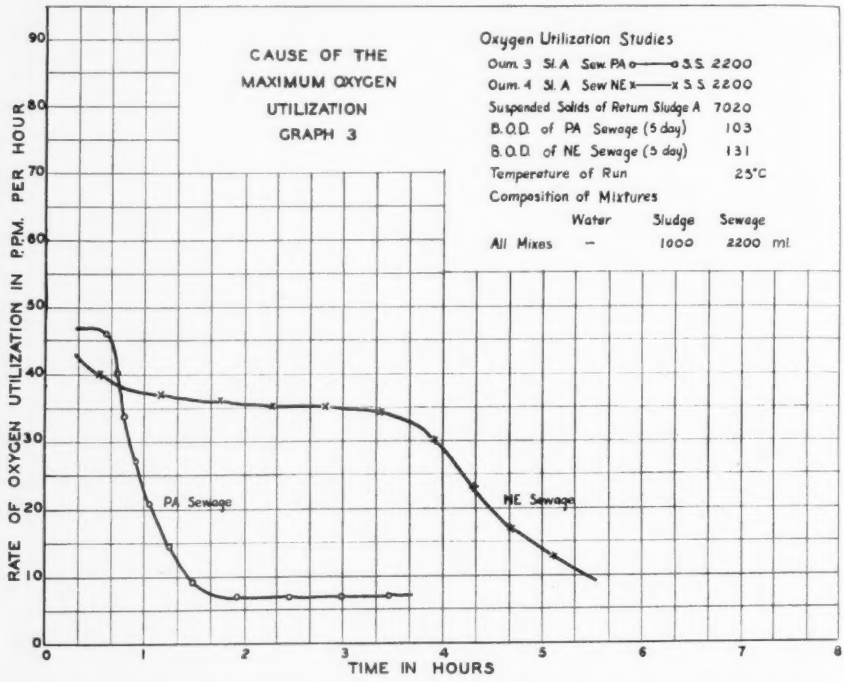
This indicated that the factor responsible for prolonging the high rates was in the soluble or colloidal portion of the sewage and that such solids were not readily oxidizable by air alone in the absence of activated sludge. Since the graphs demonstrating these results have not been included in this paper, it should be mentioned that the initial high demand for oxygen by either the filtered or preaerated sewage when treated with activated sludge was slightly less than that required by the corresponding raw sewage.

Up to this stage in the experimental work only Sewage A had been used. To determine whether other sewages also contained such a maximum prolonging factor, a sample of sewage was obtained from source B and was compared to a portion of Sewage A when each was oxidized by Sludge A. The results of this run are shown in Graph 2. Two of the



instruments, Nos. 1 and 4, were charged in an identical manner with Sewage B and Sludge A. The rate curves obtained show close agreement. Instrument 3 was charged with a similar portion of Sludge A but was given Sewage A to oxidize. The shape of the oxygen utilization rate curve obtained in the latter case is of the same type as those shown for similar mixtures in Graph 1 and is much different from that produced by oxidation of Sewage B. On the basis of 5-day B.O.D. values (Sewage A = 115, Sewage B = 165) it did not appear that the duration of the maximum rate of oxygen utilization was related to B.O.D. values, as reported by Kessler and Nichols.[1] Since the factor or factors responsible for this prolongation

of high rate of oxygen utilization appeared to be present consistently in the sewage of City A, further study of sewage from that city was thought advisable. Since up to this time all samples used had been collected at a pumping station to which the entire flow of the city converged, it was decided to take samples from three other pumping stations and nine tributary sewers. The results on two of the samples obtained from different sewers are shown in Graph 3. They again show the lack of correlation


CAUSE OF THE MAXIMUM OXYGEN UTILIZATION GRAPH 3
Oxygen Utilization Studies
Oum. 3 St. A Sew. PA o——o S.S. 2200
Oum. 4 St. A Sew NE x——x S.S. 2200
Suspended Solids of Return Sludge A 7020
B.O.D. of PA Sewage (5 day) 103
B.O.D. of NE Sewage (5 day) 131
Temperature of Run 25°C
Composition of Mixtures
Water Sludge Sewage
All Mixes — 1000 2200 ml
PA Sewage
NE Sewage
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS
0 10 20 30 40 50 60 70 80 90
0 1 2 3 4 5 6 7 8

between the duration of the high rate of oxygen usage and the 5-day B.O.D., as did the data of other runs not presented here. In general, the results of this survey showed: (1) that a definite maximum prolonging factor was present in all the sewage samples taken from contributary sources in City A; (2) that the samples of sewage producing the longest maximum rates originated from the strictly residential sections of the city. Since all the samples studied in the survey of the sewers of City A were collected between the hours of 8 and 10 A.M., it was felt that perhaps the maximum prolonging factor might be a characteristic of sewage collected at that time of day, and, consequently, a twenty-four hour survey was made on the sewage of City A at the pumping station to which all the sewage of the city flowed. Portions of sewage were collected at half-hour intervals and made into composite samples every three hours. These 3-hour composite samples were brought to the laboratory as soon as two or three had been completed. In this manner, the maximum time elapsing between the completion of collecting a sample and the start of the experi-

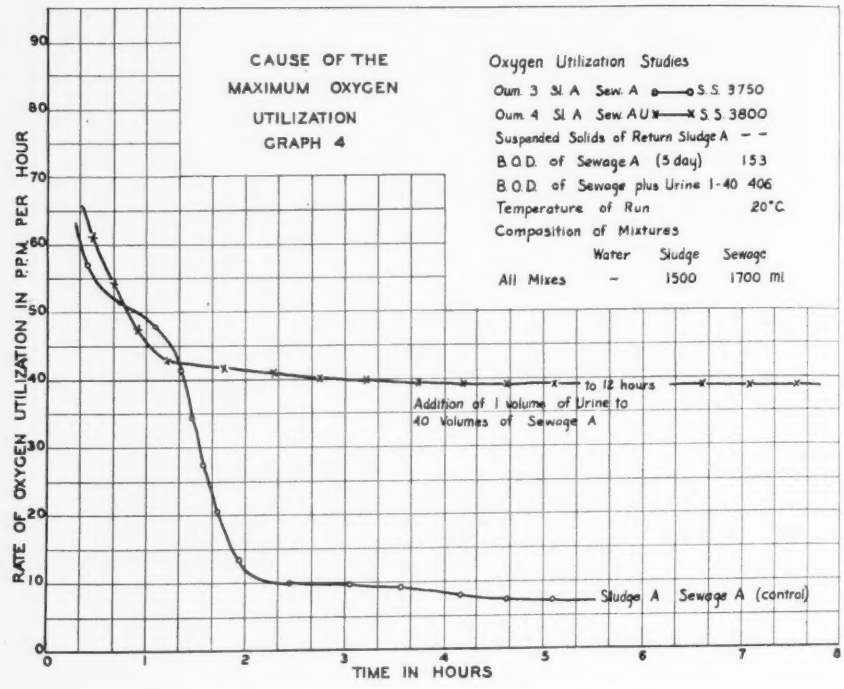
mental run to determine its characteristics did not exceed seven hours. A fresh portion of activated sludge from a stock supply was used to oxidize each sample. The results of this survey have been compiled in tabular form in Table I. They show that a decided maximum producing material

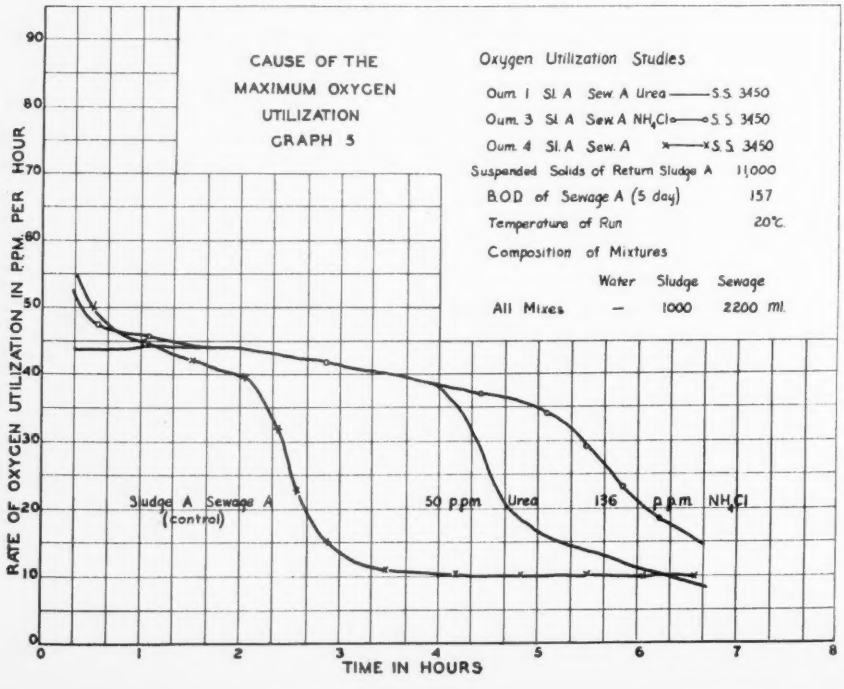
TABLE I.—*Relationship of Maximum Prolonging Factor in Sewage A to Time of Collection of Sample*

Sample	Time of Collection	B.O.D.	Maximum Rate Oxy. Util.	Hours Duration of Max. Rate
1	12–3 A.M.	142	40	1.3
2	3–6 A.M.	83	35	0.6
3	6–9 A.M.	86	35	1.3
4	9–12 A.M.	256	40	2.25
5	12–3 P.M.	290	40	1.9
6	3–6 P.M.	261	40	1.9
7	6–9 P.M.	223	37	1.8
8	9–12 P.M.	219	38	1.8

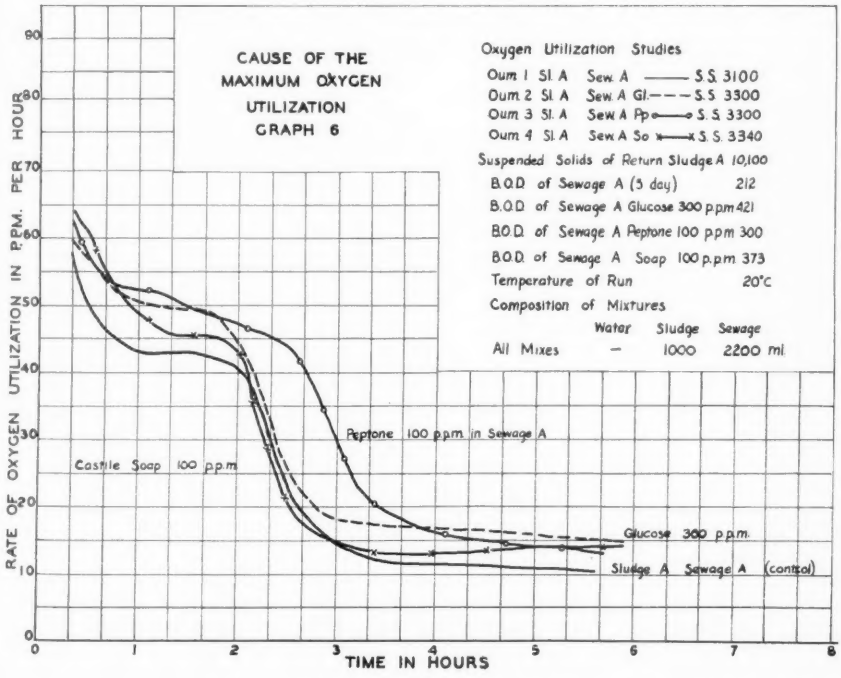
was present in the sewage of City A throughout the day and night, with the possible exception of from 3 to 6 A.M. The greatest concentration of the material producing this phenomenon appeared to be in the sample collected between 9 A.M. and 12 A.M. An estimation of the average age of the sewage as it was collected indicated that it was probably two or three hours old when it reached the sampling point. Based on this assumption, it is believed that much of the sample collected between 9 A.M. and 12 A.M. first found its way into the sewers during the early morning hours, probably between 6 and 9 A.M.

A correlation of the information obtained up to this stage in the investigation indicated that the factor responsible for prolonging the high rate of oxygen utilization was in the soluble or colloidal portion, most prominent in samples obtained from strictly residential areas, and most concentrated in the morning sewage. From these considerations it appeared that the urine content of the sewage might be responsible for the great variations. To study this possibility, a run was made in which urine was added to a portion of sewage in the ratio of one part urine to 40 parts sewage. Identical portions of activated sludge were used to oxidize the original sewage and the urine-sewage mixture. The results of this comparison are shown in Graph 4. Addition of the urine caused the high rate of oxygen utilization to be extended from about 1½ hours to at least 12 hours when the run was stopped, although a break in the curve had not yet been reached. Since the B.O.D. of Sewage A was increased only from 153 to 406 by addition of the urine, the extensive prolongation could not be attributed solely to B.O.D. increase. Undoubtedly the urine contained the prolonging factor in a concentrated form. Since the waste products in urine are principally of a nitrogenous nature, of which urea is the chief component, it was decided to study the effect of adding urea to sewage. At the same time the effect of adding ammonium chloride was determined on a separate portion. The results are shown in Graph 5 and demonstrate clearly that the high rate of oxygen utilization by Sludge A was markedly prolonged by the addition of ammonia or urea nitrogen.


CAUSE OF THE MAXIMUM OXYGEN UTILIZATION GRAPH 4
Oxygen Utilization Studies
Oum. 3 Sl. A Sew. A S.S. 3750
Oum. 4 Sl. A Sew. A U S.S. 3800
Suspended Solids of Return Sludge A
B.O.D. of Sewage A (5 day) 153
B.O.D. of Sewage plus Urine 1-40 406
Temperature of Run 20°C
Composition of Mixtures
Water Sludge Sewage
All Mixes — 1500 1700 ml
to 12 hours
Addition of 1 volume of Urine to 40 Volumes of Sewage A
Sludge A Sewage A (control)
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS

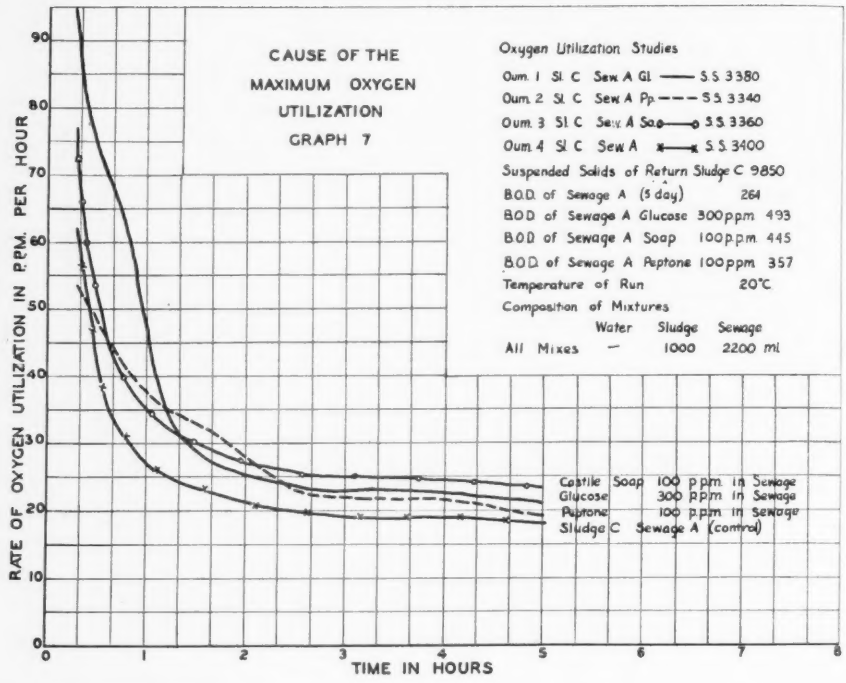

CAUSE OF THE MAXIMUM OXYGEN UTILIZATION GRAPH 5
Oxygen Utilization Studies
Oum. 1 Sl. A Sew. A Urea S.S. 3450
Oum. 3 Sl. A Sew. A NH4Cl S.S. 3450
Oum. 4 Sl. A Sew. A S.S. 3450
Suspended Solids of Return Sludge A 11,000
B.O.D. of Sewage A (5 day) 157
Temperature of Run 20°C.
Composition of Mixtures
Water Sludge Sewage
All Mixes — 1000 2200 ml.
Sludge A Sewage A (control)
50 p.p.m. Urea
136 p.p.m. NH4Cl
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS

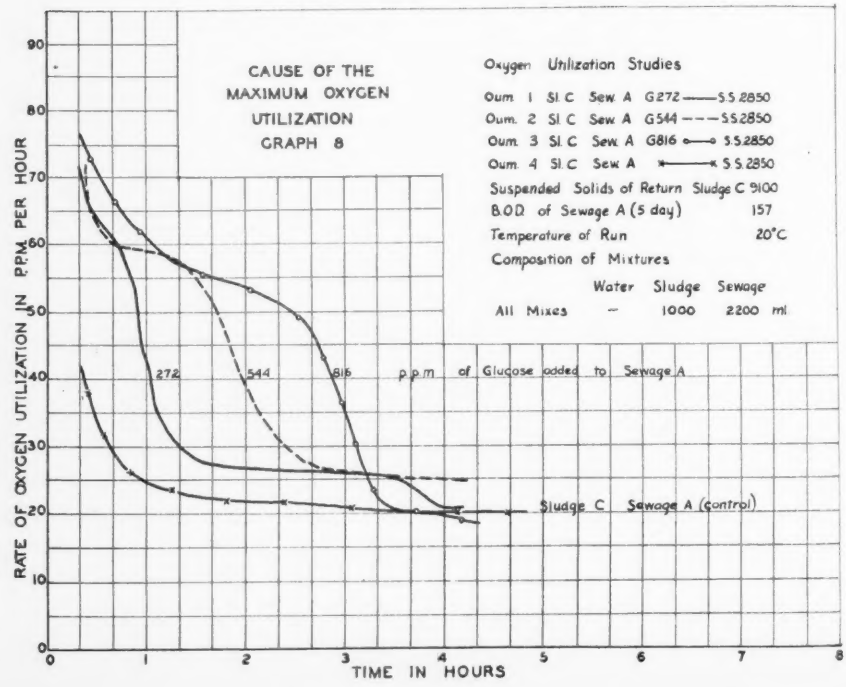
In order to determine whether other substances in sewage besides those containing readily available nitrogen were capable of exerting a similar influence, a run was made to study the effect of added carbohydrates, fats, and proteins. Glucose was used to represent the carbohydrates, peptone the proteins, and castile soap the fats. The use of peptone and castile soap was prompted by the desire to use water soluble materials. These substances were added to separate portions of the same sewage in approximately equivalent proportions, as determined by calculation of the amount of oxygen necessary to convert them to stable end-products of carbon dioxide, water, and nitrate. Each portion of sewage, including the one to which nothing had been added, was treated with identical portions of Sludge A, and oxygen utilization curves were determined for each. The results are given in Graph 6 and show definitely that with this sludge-



sewage mixture only peptone was capable of extending the time of duration of the high rate of oxygen usage. This, no doubt, was due to the nitrogen contained in it. It is to be noted that all portions of sewage receiving additional food material gave higher rates of oxygen utilization at the beginning and even at the end than did the control sample of sewage alone.

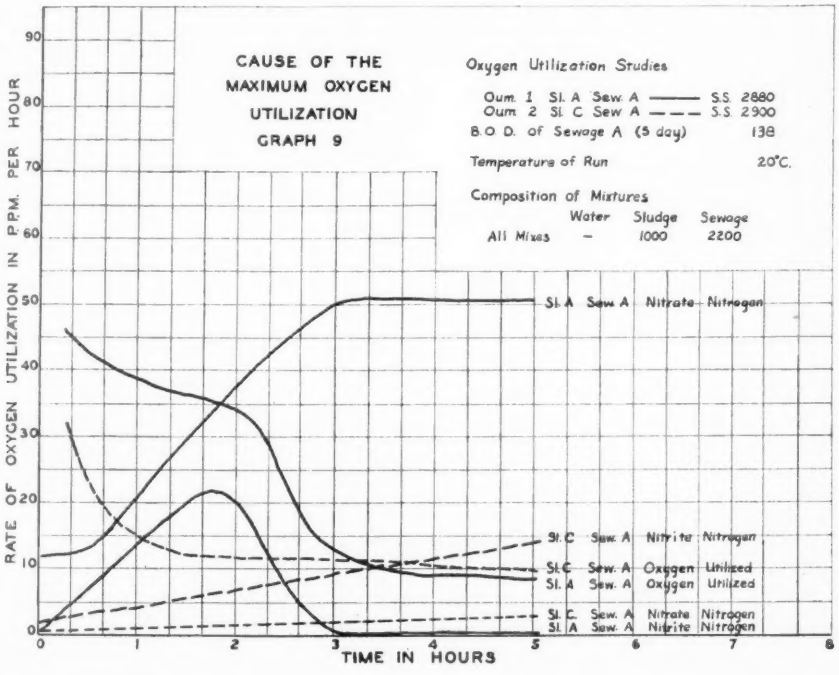
A similar run using glucose, soap, and peptone to represent the three classes of food materials was made with Sludge C. This sludge had previously shown a decidedly different oxidation curve from that given by Sludge A. The results of the run using Sludge C are given in Graph 7. Again the mixtures containing the added food material show higher rates


CAUSE OF THE
MAXIMUM OXYGEN
UTILIZATION
GRAPH 7
Oxygen Utilization Studies
Oum. 1 Sl. C Sew. A Gl. —— S.S. 3380
Oum. 2 Sl. C Sew. A Pp. - - - S.S. 3340
Oum. 3 Sl. C Sew. A Soap —o— S.S. 3360
Oum. 4 Sl. C Sew. A x——x S.S. 3400
Suspended Solids of Return Sludge C 9850
B.O.D. of Sewage A (5 day) 264
B.O.D of Sewage A Glucose 300 p.p.m. 493
B.O.D of Sewage A Soap 100 p.p.m. 445
B.O.D. of Sewage A Peptone 100 p.p.m. 357
Temperature of Run 20°C
Composition of Mixtures
Water Sludge Sewage
All Mixes — 1000 2200 ml
Castile Soap 100 p.p.m. in Sewage
Glucose 300 p.p.m. in Sewage
Peptone 100 p.p.m. in Sewage
Sludge C Sewage A (control)
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS


CAUSE OF THE
MAXIMUM OXYGEN
UTILIZATION
GRAPH 8
Oxygen Utilization Studies
Oum. 1 Sl. C Sew. A G272 ——S.S.2850
Oum. 2 Sl. C Sew. A G544 - - - S.S.2850
Oum. 3 Sl. C Sew. A G816 —o— S.S.2850
Oum. 4 Sl. C Sew. A x——x S.S.2850
Suspended Solids of Return Sludge C 9100
B.O.D. of Sewage A (5 day) 157
Temperature of Run 20°C
Composition of Mixtures
Water Sludge Sewage
All Mixes — 1000 2200 ml
272
544
816
p.p.m. of Glucose added to Sewage A
Sludge C Sewage A (control)
RATE OF OXYGEN UTILIZATION IN P.P.M. PER HOUR
TIME IN HOURS

of oxygen utilization throughout. In this case, however, the curve produced by the mixture containing glucose seemed to be exceptional. The shape of the curve during the first hour of aeration indicated that a maximum producing or prolonging material might possibly be present. To confirm this indication, another run was made using Sludge C in which the effect of added glucose in three different concentrations was studied. The results are given in Graph 8 and show that Sludge C was especially capable of oxidizing glucose. This ability resulted in high initial rates of oxygen utilization which persisted for measurable lengths of time and appeared to last for periods in proportion to the amount of glucose present.

To study still further the differences between Sludge A and Sludge C, a run was made in which each was used to oxidize identical portions of the same sewage. During the progress of the experiment, the rate of oxygen utilization was determined and also the production of nitrites and nitrates. All the data have been included in Graph 9. The results show that for



Sludge A the high rate of oxygen utilization, which lasted more than two hours, was undoubtedly related to the rapid production of nitrites and nitrates. It is of interest to note that shortly after the nitrite curve reached its maximum the oxygen utilization curve broke sharply and dropped to a much lower value. This low value was reached at about the same time as the nitrite curve reached a minimum and the nitrate curve a maximum. With Sludge C the production of nitrites and nitrates was very much slower, and their influence was practically nil in determining the characteristics of the oxygen utilization curve.

Discussion

The constituents of normal sewages contain three principal elements which are capable of being oxidized. They are carbon, hydrogen, and nitrogen. Because of the variation in composition of sewages these elements occur in widely different ratios. Since the oxidation of nitrogen proceeds independently, it is not surprising to find that activated sludges obtained from different sources show different abilities to oxidize or stabilize a given sewage. It has been known for some time that the oxidation of nitrogen in the form of ammonia nitrogen is accomplished by two very special groups of organisms, *Nitrosomonas* and *Nitrosococcus*, and that the end-product obtained by the action of these organisms is nitrite nitrogen. The conversion of nitrites to nitrates is performed by still another group of organisms, *Nitrobacter*. These organisms are strictly dependent upon the oxidation of ammonia or nitrite to derive their energy for the support of life and for reproduction; thus the growth of these organisms which will occur in an activated sludge is related to the amount of nitrification taking place. The oxidation of both carbon and hydrogen to carbon dioxide and water is known to be accomplished by pure cultures of organisms of numerous types. This obviates any necessity for symbiotic oxidation of carbon by one group of organisms and hydrogen by another.

From the preceding discussion, it can be seen that it is possible to have an activated sludge which is capable of oxidizing or stabilizing only the carbonaceous (carbon and hydrogen) portion of a sewage, leaving the nitrogen, other than that used in metabolism and reproduction, of organisms, in the unoxidized form of ammonia or urea. At the other extreme, we may have a sludge with a high proportion of nitrifying organisms, in which case the oxidation of all three elements would proceed concurrently, if conditions were strictly aerobic. An example of this class of sludge would be Sludge A, which was used in obtaining part of the information presented in this paper. It would also be possible to have sludges of any composition between the two extremes. The Sludge C used was no doubt one with a relatively small population of nitrifying bacteria, especially of the nitrate formers. Of the oxygen utilized per unit of time by such sludges, only a small portion would be due to oxidation of nitrogen, and the oxidation of this element would not be completed during the course of an ordinary run of 4 or 5 hours; consequently, a break in the oxygen utilization curve would not be observed. On the other hand, with sludges having a higher population of nitrifying organisms the rate at which oxidation of ammonia nitrogen would proceed is so rapid that the oxidation would be completed during the course of the run, and the high (C–H–N) rate would drop to the low (C–H) rate, resulting in a sharp break in the oxygen utilization curve. Addition of readily available nitrogen capable of being oxidized would of course prolong the time necessary to complete the oxidation at the high rate.

Most investigators who have reported on the oxygen utilization of activated sludge-sewage mixtures have shown that such mixtures use oxygen most rapidly during the first few minutes. This has been shown

to be the case even in the absence of nitrification and indicates that probably some forms of the carbonaceous substances are more easily oxidized than others. The behavior of Sludge C when oxidizing glucose in sewage substantiates this indication. With appreciable concentrations of easily oxidizable carbonaceous compounds present, it can be reasoned that completion of the oxidation of such components would result in a diminished oxygen demand and produce a sharp decline in the oxygen utilization rate curve, inasmuch as the oxidation of the more resistant carbonaceous components alone is involved.

Oxidation of sewage by activated sludge has been considered by many investigators to progress in two stages: the oxidation of carbonaceous material, followed by the oxidation of nitrogen, or the nitrification stage. In most cases this belief is based, no doubt, on an appreciation of the behavior of soil bacteria. That such a situation need not necessarily be the case in activated sludge-sewage mixtures was first indicated by Bartow and Mohlman [4] in 1915. They showed that the production of nitrites and nitrates started as soon as the mixture was first made and aeration begun. The results herein reported using Sludge A substantiates their early work. It would seem that, provided a nitrifying flora is present and ammonia nitrogen is available, such a condition would always be attained in the presence of dissolved oxygen.

In an earlier paper [2] it has been shown that the amount of oxygen used by two different activated sludges to give comparable B.O.D. removals from identical portions of the same sewage may be widely different. This phenomenon is readily interpretable on the basis that the sludge using the most oxygen could be one capable of causing rapid nitrification and the other slow or no nitrification. Since the 5-day B.O.D. test does not involve any appreciable nitrification, the greater stability of the nitrified effluent would not be detected and only equivalent treatment would be indicated. Ruchhoft, McNamee, and Butterfield [5] have recently shown that the oxygen consumption of non-nitrifying activated sludges when oxidizing a sewage approximates from 40 to 50 per cent of the 5-day B.O.D. value, and for nitrifying sludges the amount of oxygen consumed is usually from 100 to 150 per cent of the 5-day B.O.D. value. Recent investigations made by the author to determine the fate of the nitrogen in a sewage which was oxidized by activated sludge have shown that in normal domestic sewages the nitrogen output in the effluent correlates quite closely with the free ammonia content of the original sewage. With a good nitrifying sludge the nitrogen in the effluent appears almost exclusively as nitrates. On the basis of the above information it can readily be seen that, for a normal primary effluent with a 5-day B.O.D. of 125 p.p.m. and a free ammonia nitrogen content of 20 p.p.m., oxidation by a non-nitrifying sludge would require approximately 60 p.p.m. of oxygen for treatment, whereas with a rapidly nitrifying sludge the oxygen needed would approximate $60 + 92 = 152$ p.p.m., since each part of ammonia nitrogen requires 4.6 p.p.m. of oxygen to convert it to nitrate. Such a great increase in oxygen requirements is of considerable economic importance, and it is to be questioned whether the added expense is justified in many cases.

Summary

1. It has been shown that the high initial rate of oxygen utilization by certain activated sludge-sewage mixtures is due primarily to oxidation of nitrogenous materials, and that the duration of the high rate can be prolonged by addition of substances containing readily available oxidizable nitrogen such as urine, urea, ammonium chloride, or peptone. Addition of soap or glucose to such mixtures did not prolong the period of high oxygen usage.

2. The high initial rate of oxygen utilization by an activated sludge-sewage mixture, in which nitrification was a minor factor, was found to be due to oxidation of carbonaceous matter. Glucose was found to prolong the high rate in proportion to the amount present. The addition of soap or peptone did not appear to cause similar effects.

3. The duration of the high rate of oxygen utilization by activated sludge-sewage mixture has been found to be related to specific components of sewage in the cases studied, rather than to the combined effect of all the components. Sharp breaks in the rate curves usually indicate the completion of the oxidation of one component.

Acknowledgments

The author wishes to express his appreciation to Dr. W. D. Stovall and Dr. M. Starr Nichols, director and chief chemist, respectively, of the Wisconsin State Laboratory of Hygiene, for providing laboratory space and equipment for the conduct of these studies, also to Messrs. H. O. Lord and J. C. Mackin, chief engineer and plant superintendent, respectively, of the Madison Metropolitan Sewerage District, for their cooperation and assistance in the collection of sewage samples.

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Plant Operation

THE DETROIT SEWAGE DISPOSAL PROJECT*

By George R. Thompson

City Engineer, Detroit

Editor's Note.—The following papers, by Messrs. Thompson, Morrill and Rudd, have been selected from the symposium on the Detroit plant design presented at the Michigan conference. There is an additional paper by M. F. Wagnitz on the intercepting sewers and regulator works. The paper by Mr. Rudd has been shortened considerably. For the complete papers, see Bulletin 84 of the Michigan Engineering Experiment Station, East Lansing. Price, 25 cents.

The City of Detroit is completing a sewage interceptor and treatment plant at a total cost of approximately $28,000,000. This plant will serve the major portion of the metropolitan area. It will take care of sewage treatment for not only the City of Detroit, but the enclosed cities of Hamtramck and Highland Park and the adjacent cities of Grosse Pointe Park, Grosse Pointe Farms, Grosse Pointe Shores and possibly other nearby territory.

Like most other cities, the need for sewage treatment in Detroit was first recognized in connection with the protection of the public water supply. In the year 1873 Water Works Park, on the American shore of the Detroit River, opposite the upper end of Belle Isle, was purchased and here was built the city's water plant. The location was selected in the belief that water taken from the middle of the adjacent American channel of the Detroit River would be forever free from pollution. However, in less than fifteen years surveys indicated that pollution was reaching the intakes from Port Huron, on the St. Clair River. Subsequently, the intake was again moved to what was then considered a safe location; but, again, in less than ten years it became necessary to chlorinate the water in order to make it safe for domestic consumption. However, pollution continued to increase, so that within another ten years it was necessary to construct a filter plant.

The pollution of the Detroit River has never been merely a local problem, but, rather, has been an international one, since the river is one of the boundary waters between the United States and Canada. On January 11, 1909, the Waterways Treaty was signed by the two countries, providing that neither should pollute the waters to the injury of health or property of the other. Studies subsequently made by the International Joint Commission conclusively showed gross pollution in the Detroit River and that the intakes of both Canadian and American cities were located in such polluted areas. This condition, requiring a most careful

* Presented at the Annual Conference of the Michigan Sewage Works Association, East Lansing, March 30, 1939.

and expensive type of treatment, has continually added to the cost of water to those communities bordering on the Detroit River.

The first actual plan for sewage treatment for Detroit was prepared by Mr. Clarence W. Hubbell, Consulting Engineer, in 1916. The plan proposed a high and low level interceptor with Imhoff treatment, followed by chlorination, at two sites. This plan was based on serving a population of 950,000 and was estimated to cost $6,091,000. The proposed plan was approved by the International Joint Commission as capable of meeting the treaty obligations.

In 1925 a new study of the sewage treatment problem was again made. Mr. Clarence W. Hubbell and the late Messrs. Harrison P. Eddy and John H. Gregory were retained as Consulting Engineers. This board recommended the construction of a river interceptor running to a single plant located on the Detroit River, just below the Rouge River. This plan was also based on Imhoff treatment, and provided for a population of 2,400,000 and was estimated to cost $39,600,000.

Work on the interceptors was started shortly after the report was made and about 4 miles of interceptors were built from the east side of the city at Fairview pumping station to the center of the city at Bates Street, at a cost of about $5,000,000. Before any work was started on the plant itself, restrictive legislation was enacted which prevented the plant being built in the location recommended in the City of River Rouge.

In 1929 legislation was obtained which enabled the sewage treatment problem to be considered on a county-wide basis. Soon after the Public Works Administration was created in 1933, an unsuccessful attempt was made by Governor Comstock to have the sewage disposal problem of the counties of Macomb, Wayne, Oakland, and St. Clair considered as a 100 per cent Federal project because of the 1909 Waterways Treaty obligations.

The project was necessarily modified so as to include only Wayne County, and an application was filed on July 19, 1934, for a $23,000,000 City-County project. After the City-County application was disapproved, a new application, covering only the City of Detroit, was filed for $20,000,000. The City received and accepted an offer from the P.W.A. in the fall of 1935 to aid in the financing of the City project. The offer provided that the P.W.A. would purchase $11,000,000 worth of Sewage Revenue Bonds and make a 45 per cent grant, not to exceed $9,000,000, on the cost of the project. The first contract, that for one section of the Detroit River Interceptor, was let in December, 1935. Since that time, practically all the major contracts have been awarded, and the project is now approximately 85 per cent complete and scheduled to be placed in preliminary operation in the Fall of this year.

The plant is essentially simple, although large, occupying as it does an area of 72 acres. The treatment consists of sedimentation with incineration of sludge and chlorination of effluent. It will serve the present population of 1,600,000, and is designed eventually to accommodate a population of 2,400,000. The plant is located at the westerly extremity of the City of Detroit, and about one mile from the Detroit River, into which the effluent is discharged after passing under Zug Island in an 18-foot outlet conduit.

THE DETROIT SEWAGE TREATMENT PLANT*

By Arthur B. Morrill

Associate Civil and Sanitary Engineer, City of Detroit

The Detroit Sewage Treatment Plant, although unusual in the matter of size, is comparatively simple in principle. The entire sewage flow is brought by two interceptors to a pumping station and there lifted to the screenings racks and grit chambers. The sewage passes on through Venturi meters to the sedimentation tanks, while the screenings and grit are diverted to the same incinerators which handle the sludge. The flow may be chlorinated either before or after passing through the sedimentation tanks. The effluent is discharged to the Detroit River through a conduit in which the detention time is so long that no contact tanks for chlorination are required. It is possible in case of an emergency to by-pass the flow from the outlet end of the grit chambers directly to the outlet conduit.

Sludge will be pumped continuously from the sedimentation tanks and most of it will go directly, after chemical conditioning, to sludge filters, thence to incinerators. Provision is made for partial digestion of ⅛th of the sludge, followed by elutriation. The elutriated sludge will be dewatered on vacuum filters and incinerated in the same way as the raw sludge. City water will be used for elutriation. The elutriate, the filtrate from sludge filters, and the overflow from the digestion tank will be returned to the sedimentation tanks.

Basic Data

A great deal of work was necessary to obtain an accurate estimate of the quantity and quality of sewage to be expected at the plant. In many cities the sewage flow is concentrated in a small number of outlets before sewage treatment is considered, so that by gauging and sampling these outlets an accurate idea of the amount and nature of the sewage can be obtained. In Detroit it was necessary to gauge and sample more than 40 outlets to obtain this information.

The estimates of the Board of Consulting Engineers in 1936 were an average sewage flow of 175 gallons per capita per day with a removal of suspended solids of 0.20 lb. per capita per day. As the result of the program of sewage gauging and sampling, it is now believed that this latter figure in particular is about 25 per cent too high, so the anticipated removal of suspended solids is 0.16 lb. per capita per day. The best available estimate as to the average character of the sewage to be received is shown in the following table.

This information is based on work on 38 sewer outlets representing a total flow of 229 m.g.d.

Since the effluent is to be chlorinated and the cost of chlorine will represent a considerable part of the total cost of treatment, the actual chlorine demand at the plant is a matter of great importance. It is

* Presented at the Annual Conference of the Michigan Sewage Works Association, East Lansing, March 30, 1939.

Estimated Average Character of Detroit Sewage

	Parts per Million
Total Solids	707
Total Volatile Solids	399
Suspended Solids	233
Suspended Volatile Solids	149
5-Day B.O.D.	146
Chlorides	84
Chlorine Demand	6.7

realized that the result found in the combined flow may not be a simple summation of the results found in individual sewer outlets, particularly in warm weather. This matter will need careful consideration in the future. It may even prove economical to pre-chlorinate at points in the interceptor system to prevent development of septic conditions in that part of the sewage with unusually long time of travel.

Sludge filtration and incineration calculations have been based on an assumed removal of 55 per cent of the suspended matter present in the raw sewage. The plant will naturally have little effect on the dissolved matter present.

Results Expected

The extent of treatment proposed, although considerably less thorough than in many Michigan cities, appears to be entirely ample for the Detroit situation. It is interesting to point out the extremely favorable situation of the city as regards disposal by dilution. The Detroit River above the city is practically saturated with dissolved oxygen and in good sanitary condition. Whereas the flow of many rivers varies widely between flood and low water conditions, the discharge of the Detroit River is very uniform from day to day and from year to year. Even in 1970, when the population served by the Detroit plant is expected to reach 4 million, the minimum discharge of the Detroit River will still be about 150 times the average rate of sewage flow. Thus the depletion of oxygen in the river as a result of the oxygen demand of the effluent discharged, which is a controlling factor in the majority of treatment plant installations, is of no practical importance at Detroit. Even without treatment the depletion of dissolved oxygen is important only near sewer outlets and would not be important at all if the entire sewage flow were well mixed with the entire flow of the river. While it is difficult to predict for the long future, it seems certain that secondary treatment for the purpose of oxidizing the dissolved organic matter in the effluent will not be needed in Detroit for decades, if ever.

While the demands on the Detroit plant in this respect are less rigid than is often the case, the need for excellent bacteriological results is unusually great. Two public water supplies serving nearly 50,000 people are taken from the American half of the Detroit River below the city. While both of these have been successful in securing a uniformly safe effluent from a very badly polluted raw water, the situation is hazardous and should not be allowed to continue. A recent tabulation of the raw water analyses of the Wyandotte supply indicates that 50 per cent of the

time the M.P.N. coliform index exceeds 20,000, and that 10 per cent of the time it exceeds 220,000. About 2 per cent of the time the index probably exceeds 1,000,000.

Aside from its use for potable water supply the Detroit River has great recreational possibilities which are now much limited by sewage discharge. Health authorities do not now approve of bathing at any point of the entire length of the American side of the Detroit River from Lake St. Clair to Lake Erie. Thus the removal of pathogenic bacteria from the effluent is one of the prime purposes of the Detroit plant. The extent to which chlorination will be practiced is receiving careful consideration. It is most obviously necessary in the months of July, August, and September when the coliform indices are higher due to the high water temperature and when also the river is likely to be more used for bathing. The average index for August, for example, is about six times as great as the corresponding figure for October, November, and December.

Variation in Rates of Flow

An important matter in any sewage treatment plant is the variation between the average rate of sewage flow and the maximum and minimum rates which may occur at certain times during the year. These variations are less extreme in the largest cities, where the time of flow from the most remote districts is much more than that from districts nearest the plant. Also the storage capacity of the interceptor is such that the actual rate of pumpage can be determined to some extent by the plant operators. It is believed likely that, except in time of rain, it will never be necessary to operate the plant at a rate more than 30 per cent in excess of the annual average. By using various combinations of pumps the total discharge can be regulated to the nearest 50 m.g.d.

In using the storage capacity of the interceptor to equalize the flow, care must be taken to avoid septic conditions or depositing velocities. Since the velocity in the interceptor when not backed up will be about 6 ft. per second, a certain amount of backing up can be permitted without any danger of depositing velocities. Equalizing the flow in this manner will probably improve the sedimentation results. Studies will have to be made to determine whether such storage in the interceptor increases the chlorine demand or has any other unfavorable effect.

General Design

The larger interceptor paralleling the Detroit River comes to the pumping station from the northeast, with a somewhat smaller interceptor coming from the west. The racks and grit chambers are immediately adjacent to the pumping station. Through curved conduits the sewage then flows to the sedimentation tanks. The tank effluent flows in a high level conduit to a junction shaft close to Jefferson Avenue. At the shaft it drops down to a deep tunnel which conveys it about 6,000 ft. to the point of discharge in the Detroit River. North of the grit chambers are located the filter and incinerator building, the switch house, the laboratory, and the chlorination building. West of these buildings are located the

digestion tank, the elutriation tanks and the gas holder. West of the sludge digestion tank are located two large ash storage lagoons, of such size as to hold one year's accumulation of ash from the incinerators.

Rack and Grit Chambers.—The main pumps discharge through flumes built in the concrete walls of the circular pumping station and these flumes discharge through curved channels leading to the screening racks and grit chambers. Each sewage pump has its independent channel, its own set of mechanically cleaned racks and its own grit chamber. Since the pumps are of constant capacity, except for the effect of some variation in head, and since the depth of flow in the grit chambers varies automatically nearly in the same proportion as the rate of flow, the velocity of flow in any grit chamber is nearly constant under all conditions of operation. When any pump is not operating the corresponding grit chamber will be out of service and may be drained.

Only six of the eight rack and grit chambers have mechanical equipment installed, corresponding to the six pumps provided for present installation. The bar racks have ¾-in. clear openings. The rack cleaning devices discharge onto a belt conveyor, everything above the operating floor being enclosed in a steel housing. The grit chambers will be continuously cleaned by a V-bucket collector. These buckets discharge onto a scraper conveyor in a concrete channel, also covered with a steel housing. After draining, the grit is transferred to a belt conveyor, which transports it eventually to the incinerator building. The outlet 100 feet or more of length of the grit chamber is covered with a low concrete slab roof, to be covered with earth and grass.

The grit chambers are from 12.83 to 19.17 ft. wide, depending on the various pump capacities, but each is 150 ft. long and about 15 ft. deep. Since the velocity is designed to be one foot per second, the detention time is 2½ minutes as compared with a time of one minute generally used.

The design is unique in that, except when the housings are opened for servicing, no sewage or sewage solids will be visible to visitors to the rack and grit chamber building. The space inside the housings and above the sewage surface is ventilated, the air being drawn through ducts to a stack. Thus it is hoped to avoid nuisance in the rack and grit building, a part of the plant that is often troublesome in this respect.

It might be interesting to discuss why such deep and large grit chambers were selected. It is generally considered that the capacity of a grit chamber is a function of its surface area, not of its volume, so that the volume for a given capacity is least when the chamber is shallowest. If shallow grit chambers 6 ft. deep had been selected for this unusually large plant the limitations of velocity would have required that the total width of grit chamber be about 360 feet. The cost of racks and collecting mechanisms would have been increased and a building to house the equipment would have been more expensive. The collecting channels leading to and from the grit chamber would also have been more costly. Comparative estimates were made of grit chambers 7½ and 15 ft. deep, having the same surface area but the deeper chambers having double the volume. Rather curiously, the larger grit chambers prove, for this large plant, to be less expensive than smaller ones. Although the grit chambers

have a detention time of 2½ minutes and are 15 ft. deep, it is not expected that the grit removal will be any different than if they had a detention time of one minute and were 6 ft. deep.

Conduits and Meters.—Leaving the grit chambers the sewage enters two concrete conduits, each 10 ft. square inside. Near the inlet end of the conduits provision is made for pre-chlorination of the flow. Farther on, the conduits pass through Venturi meter chambers. The meters are constructed of reinforced concrete with cast-iron bronzed lined throats 10 ft. high and 5 ft. wide. Since the throats have the same height as the conduits, there is no opportunity for trapping either solids or gases. The meter bodies for these Venturi meters are located in the operating gallery of the near-by sedimentation tanks.

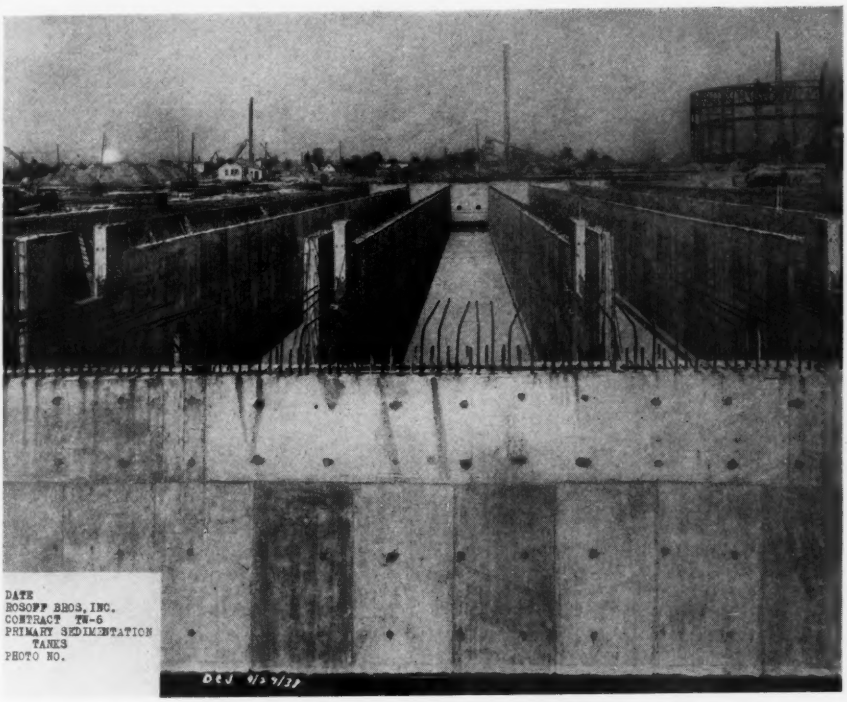

FIG. 1.—Sedimentation tank from outlet end. Each unit consists of seven flow channels. Concrete cover not yet placed. Pumping station steel work at right.

Sedimentation Tanks.—There are eight sedimentation tanks, constructed in pairs, with a 20-ft. earth fill between each pair and the next (Fig. 1). Across the north end of the entire layout is an operating gallery for controlling the flow into the tanks. The sewage enters through a conduit below the floor of the gallery. The effluent flows over weirs at the south ends of the tanks (Fig. 2) and is combined in the collecting channel leading across the south end of the layout and then discharging from the east end to the outlet conduit and eventually to the river.

The sedimentation tanks are unusual in several respects. First, because of their length and design velocity. They are about 270 ft. long with a nominal detention time of 90 minutes at average flow and 49

FIG. 2.—Effluent weirs at outlet end of covered sedimentation tanks. Covered effluent channel at right.

minutes at maximum flow. This means that the nominal velocities are 3.0 ft. per min. at average flow and 5.5 ft. per min. at maximum flow. In planning for the plant there was considerable discussion as to whether sedimentation efficiency would be satisfactory at these velocities. Al-

though experience with tanks of such length was very limited at the time the design was determined, the evidence seems to be that such velocities will give entirely satisfactory results. It is important, however, that the distribution of flow over the tank cross-section be as uniform as possible, that is, that the actual velocity at all points in the cross section be as close as may be to the nominal velocity. The considerable length of the tanks made necessary the operating of the sludge collectors at a velocity of 2 ft. per min. which is twice the speed ordinarily used.

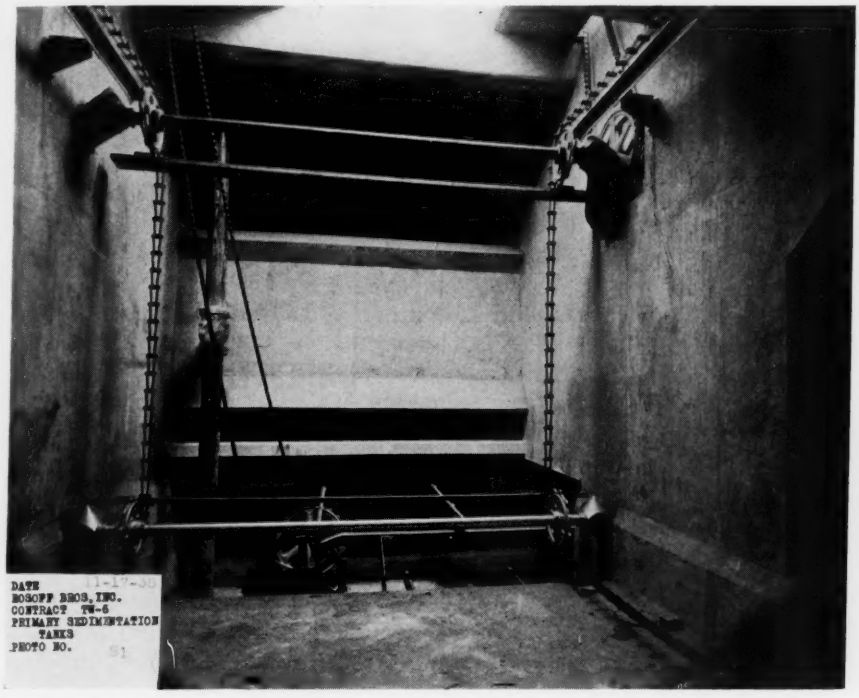

FIG. 3.—Influent end of one flow channel of sedimentation tanks. Showing main sludge collector and sludge cross collector with sludge line from sump to pumps in adjacent gallery. Inlet behind especially designed concrete baffle wall.

The tanks are unusual in a second respect in that they are covered with a low concrete slab roof, close to the water surface, which is covered with 18 in. of earth and grass. There is little precedent for the use of such covers, but covering was decided to be essential to avoid danger of nuisance from the plant. On account of the great area of sewage surface and the proximity of the plant to the built-up sections of the city, it was decided that unusual precautions were necessary in this respect. Each tank, 117 ft. wide inside, is divided by continuous longitudinal walls into seven separate channels 16 ft. wide, 14 ft. average depth, and 272 ft. long. Each channel has two 18-in. inlet valves and at the outlet end collecting weirs. The bottom is cleaned and the surface skimmed by moving-flight sludge collectors (Fig. 3). Each of these channels will act hydraulically

much as a separate tank, except that there are doorways through the intermediate walls at each end and other openings for the passage of the scum collectors and sludge cross collectors. Thus one channel cannot be drained without emptying all the other six in the same tank, and any inequality of flow between channels will tend to equalize by flow through the openings in the intermediate walls.

The continuous training walls in these tanks are unusual, but due to the necessity of some means of supporting the roof and the return runs of the sludge collectors, they could be provided with a relatively small increase in cost. They are, of course, very desirable from a hydraulic point of view. With the guide walls, the water surface protected from the wind by the roof, and carefully designed inlet and outlet devices, it is hoped that the distribution of flow in the tanks can be made much more uniform than is often the case.

The plans provide for an especially designed baffle, running the full width of each channel in front of the two inlet openings. The dimensions of this were selected by hydraulic experimental work carried on by Professor George Hubbell of Wayne University, following the ideas incorporated in somewhat similar baffles designed by Hubbell, Hartgering and Roth for the East Plant at Dearborn Having an opening at the lower half of the baffle and introducing part of the flow at this point prevents accumulations of sludge deposits. Hydraulic model experiments showed that a baffle of this shape would be successful in producing uniform distribution of flow in all parts of the tank except in a section close to the baffle.

The sludge cross collectors receive sludge drawn to the influent end by the main collectors and transmit it to one corner of the tank. From here it is drawn by pumps located in the pipe gallery and discharged through pipe lines for further treatment.

Digestion Tank.—It was originally intended to treat all of the sludge produced by partial digestion by building eight digestion tanks, each having a capacity of 300,000 cu. ft. Largely because of limited funds, but partly because of the question as to the necessity and economy of digestion, the decision was made to build only one of these proposed eight large digestion tanks. Preliminary studies indicate that the economic balance between digestion and the treatment of raw sludge is close. Much will depend on the relative cost of chemicals and the production rates on vacuum filters, although doubtless less care would be necessary to avoid nuisance in the filtering of digested sludge than of raw sludge. The construction of the single large digestion tank will serve as a full-scale experiment to determine whether digestion should be used for the entire plant. Whatever the result of the experiment, it seems certain that the single tank will pay for itself in saving of chemicals, increased rates of filtration, and equalizing of peak sludge loads.

The tank is of the floating cover type. The inside diameter is 105 ft. and the water depth at the side wall is 30 ft. The conical hopper 12½ ft. deep. Provision is made for heating by 18 coils of 4 in. steel pipe sup-

ported on steel frames near the periphery of the tank. The total length of heating pipe in the tank is 5420 ft.

Elutriation Tanks.—Two elutriation tanks have been provided. These are planned to operate in series on the counter-current basis and have sufficient capacity to treat the sludge from the one digestion tank. Raw sludge will not be elutriated. It was determined that if digested sludge, which is high in soluble nitrogenous compounds, were mixed with two or three volumes of relatively clean water and then allowed to settle, 75 or 80 per cent of the soluble constituents could thus be removed from the sludge. By repeating the processes the removal could be much increased. It is believed that by elutriation the coagulant requirements will be made much less, with important cost savings. Each elutriation tank is 18 ft. wide, 7 ft. long inside, with a depth of about 12½ ft. At the end is an operating gallery with provision for mixing the digested sludge with elutriating water once used and also mixing the once elutriated sludge with clean water. The mixing will be done by compressed air diffused with porous plates.

Sludge Filtration.—After elutriation one-eighth of the sludge will be pumped to the filter building, to which also will come the other seven-eighths pumped directly from the sedimentation tanks. The two sludges will be handled separately in the filter building so dependable information will be obtained as to the production rates possible for each of the two methods.

In the layout of the sludge filter building, provision is made for the eventual installation of twelve vacuum filters, each of 500 sq. ft. filtering area. The eight filters centrally located in the building are being installed at this time. At the west end of the building are located the vacuum pumps, three to be installed at this time with provision for a fourth.

It is expected that ferric chloride will be used as a coagulant. The chemical will be received in rubber-lined tank cars and transferred to rubber-lined steel storage tanks in the basement of the chemical building, from which it will be pumped to the conditioning tanks. Lime will also be used for conditioning of raw sludge and will be stored in four tanks, each of 60 tons capacity. The vacuum filters are 11.5 ft. in diameter and 14 ft. long. Blowers, filtrate pumps, ferric chloride pumps, ferric chloride feeders, pneumatic lime conveyors, lime feeders and slakers, sludge bucket elevators and sludge mixing tanks are also provided in the filter building.

Chlorination.—Chlorine will be received in tank cars. These will be spotted on special stub-end tracks, protected by derails from accidental bumping by a moving car while the chlorine lines are connected. The chlorination building is 35 ft. by 50 ft. inside and the present installation will consist of nine chlorinators, each to have a capacity of 6,000 lb. per day. Due to the high rate of chlorine withdrawal from the tank car, it is not practicable to remove the chlorine as a gas. It must be removed as a liquid through 1-in. pipes and volatilized in nine evaporators inside the building. The evaporators will be heated with hot water.

MECHANICAL DESIGN OF THE DETROIT PLANT. INCINERATORS AND POWER PLANTS *

By William C. Rudd

Associate Mechanical and Electrical Engineer, City of Detroit

Sludge Incineration

All sewage solids consisting of sludge cake, screenings and grit, containing a moisture content of approximately 70 per cent in the sludge cake, 85 per cent in the screenings and 35 per cent in the grit, will be incinerated. The total weight of wet solids, as of the year 1939, incinerated per 24 hour day is estimated to be 1,356,500 lb. or 679 tons average load, with a maximum daily load of 2,400,000 lb. or 1200 tons.

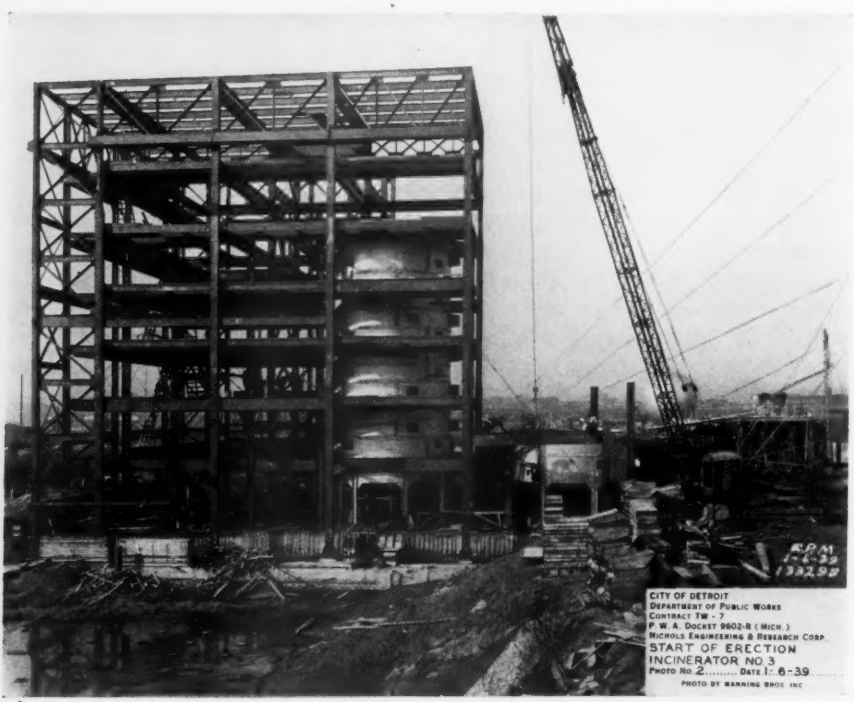
CITY OF DETROIT
DEPARTMENT OF PUBLIC WORKS
CONTRACT TW - 7
P. W. A. DOCKET 9602-R (MICH.)
NICHOLS ENGINEERING & RESEARCH CORP.
START OF ERECTION
INCINERATOR NO. 3
PHOTO NO. 2 DATE 1- 6-39
PHOTO BY MANNING BROS. INC

Fig. 4.—Sludge incinerator building framework with shell of one 22 ft. incinerator finished and another started.

Incinerator Equipment.—The initial installation of incinerator equipment will consist of four units of multiple hearth incinerators, with provision allowed in design of building for two (2) future units. The building housing this equipment is approximately 72 ft. wide by 208 ft. long (Fig. 4).

* Excerpts from paper presented at the Annual Conference of the Michigan Sewage Works Association, East Lansing, March 30, 1939.

Each incinerator is of the twelve (12) hearth type, 23 ft. 3 in. outside diameter of shell, with a total height of approximately 53 feet. Each incinerator unit will be equipped with air pre-heaters, cooling air fans, hot air fans, hot gas fans and fuel oil burners.

Fifteen hundred (1500) gallons of fuel oil will be required to start each cold dry incinerator, after which no auxiliary fuel will be required.

The rated capacity of each unit is 300 tons of wet sewage solids per day, with an average moisture content of 70 per cent. The installation is designed to take care of a 10 per cent overload.

Conveyor System.—For feeding wet sewage solids to the incinerators a complete conveyor system consisting of 25 troughed endless belt conveyor units will be operated. No other type of conveyor system was found to be satisfactory for this purpose, because of the sticky character of refuse materials.

All of the conveyor units will usually be operated as a unified system, but each separate conveyor section in the entire system can be operated alone or in combination with other units if desired, so as to feed one or more incinerators. A complete electrical system of interlocking connections, from the incinerator drives to the sources of supply, has been devised so that the stoppage of a conveyor will automatically stop the conveyor or conveyors feeding same.

Four weighing mechanisms are installed in the conveyor system, which will at all times show the amount of screenings, grit and sludge cake fed into the incinerators. All belts are 24 in. wide, and operate at a speed of about 150 ft. per minute, giving a maximum capacity of approximately 75 tons per hour.

Ash Disposal System.—The problem of ash and dust disposal from the incinerators is of importance, inasmuch as an average of about 99 tons of dry ash and dust per day is expected to be produced during operation in the year 1939. Ash is delivered from the incinerators at a temperature of 800 to 900 degrees Fahrenheit.

After considerable study and investigation of mechanical, pneumatic, and hydraulic ash handling systems, the type selected was the hydraulic ash sluicing system, because it had the advantage of handling very hot ash and pumping large quantities of refuse materials to considerable distances from the plant, through pipe lines laid underground.

The ash refuse will be pumped to two ash lagoons, each approximately 250 ft. by 500 ft. by 6 ft. deep, which will provide six months storage space each. Water used for sluicing will drain from the ash refuse and the ash will accumulate until removal by means of a steam shovel, clam shell and trucks to a permanent dump. It is characteristic of sewage incinerator ash to retain water equal to its own weight, which must be handled with the ash. During the year 1939, an average daily load of 185 tons of wet ash will accumulate in the ash lagoons.

The hydraulic ash sluicing system is operated by means of a 90 H.P. high pressure sluicing pump which delivers 900 g.p.m. at 185 ft. head. The incinerator ash is sluiced to a central ash pit, where ash pumps operated

by means of 100 H.P. motors pump the ash-laden water approximately 1200 ft. to the ash lagoons.

Gas Holder.—It is estimated that 135,000 cu. ft. of sludge gas, at a pressure of 6 in. water, will be produced daily from one 105 ft. diameter sludge digestion tank. Approximately 10 per cent of this gas will be compressed into a gas holder and 90 per cent used in a gas engine. In order to utilize this gas to the best advantage, a system has been designed wherein the gas produced will be conveyed to a gas engine-generator of sufficient capacity to burn the gas produced, and any excess gas will be compressed into a gas holder for use under steam boilers or in the engine.

A study was made of various types of gas holders with several methods of operation, namely, the low pressure or gravity type, and the medium pressure type. For reasons of economy, the medium pressure type was selected. In this, gas flows directly from the digestion tank to the gas engine and any gas not so utilized is compressed to 30 lb. per sq. in. and stored in the gas holder, flowing from the gas tank through a reducing valve to the boilers or being bypassed to the engine.

A spherical gas holder of 36 ft. diameter has been installed. This holder has a volume of 24,400 cu. ft. and will have capacity to store 24,700 cu. ft. at 6 in. water pressure or 74,370 cu. ft. at 30 lb. per sq. inch.

The cost of a 75,000 cu. ft. low pressure or gravity type gas holder would be approximately $32,000, and with fixed charges at 6 per cent and maintenance cost at 1 per cent, the total annual cost would be $2,240. The cost of the spherical 24,400 cu. ft. medium pressure gas holder was approximately $19,000 and with fixed charges at 6 per cent and maintenance cost at 1 per cent, the total annual cost will be $1,330. The operating cost for gas compressors will be about $120 per year. The selection of a medium pressure gas holder, therefore, made a saving of $13,000 in the first cost and a saving of $790 in the total annual cost.

Gas Engine-Generator

A gas engine-generator will be installed to utilize the sludge gas produced as a by-product of the digestion process. Besides generating electrical energy, the waste heat from exhaust and engine jacket will be passed through a waste heat boiler and a gas-engine jacket-water heat exchanger, thereby heating the water circulated through the digestion tank.

Type of Engine and Generator.—The four cycle, six cylinder, 364 horse power stationary type gas engine operates with a residual minimum pressure at the gas inlet to the engine of 3 in. of water. The engine is directly connected to an open type 240 KW. induction type generator, the synchronous or no load speed of which will be 400 R.P.M. This generator is connected to receive excitation from and deliver energy to the plant power system. The generator is designed to operate in parallel with this system and cause no unbalancing or other disturbances. The heat rate of the engine is 9500 B.T.U. per brake horsepower hour at full load, distributed as follows:

	Per Cent	Amount of Heat Used Per Cent
Mechanical work	26	26
Water jacket	35	33
Exhaust	26.5	21
Losses and unaccounted for	12.5	0
Total	100	80

The heat transfer to the digestion tank circulating system at full load will be 1,150,000 B.T.U. per hour from the engine jacket water heater and 724,400 B.T.U. per hour from the exhaust gas waste heat boiler, or about 1.2 million B.T.U. per hour as by-product heat recovered and used.

When waste heat from the engine jacket and exhaust is insufficient to heat the digestion tank, the temperature of the circulating water will be automatically increased by means of steam operated water storage heaters.

The cost of the gas engine was approximately $30,000 and with fixed charges at 6 per cent and maintenance cost at 1 per cent, the total annual cost will be $2100.

The total amount of power to be generated is estimated at 1,500,000 Kw.hrs. per year, at an estimated cost of $0.003 per Kw.hr.

Boiler Plant

Considerable study was given to the boiler plant design. Two types of boiler installation were considered, namely, horizontal return tubular and bent water tube boilers. The portable type of fire tube boiler, without brick settings, but covered with plastic or block insulation, was not considered suitable for this plant. The utilization of waste heat from the incinerators by means of waste heat boilers was also considered, but due to the low temperature of incinerator stack gases (about 700° F.) and the very high moisture content, together with the probability that efficiency of incinerators would decrease and result in the use of auxiliary fuel, incinerator waste heat boilers could not be justified.

While the main use of steam boilers for this plant is for heating purposes, high pressure steam is required for soot blowers, boiler feed pumps, auxiliary and related equipment.

The selection of water tube boilers was based on the necessity for conserving space, and the fact that water tube boilers readily respond to forcing or overloads of from normal to 250 per cent rating or more, thus permitting the installation of two water tube boilers as against four fire tube boilers.

One 50 H.P. boiler will be installed for the summer load, because some steam is required during all periods of the year.

Each unit of two 200 H.P. water tube boilers will be equipped with combined fuel oil-gas burners. Combined fuel oil-gas burner equipment suitable for use with #5 fuel oil and sludge gas was selected because fuel oil is absolutely necessary for operation of the incinerators, and a fuel oil storage of 60,000 gallons capacity is required for this purpose. Oil-gas equipment also permitted the elimination of a coal handling and

storage system, together with the attendant ash handling system, providing much needed space for other purposes.

It is estimated the boiler plant will be required to operate under the following conditions:

Maximum load	540 boiler horse power
Average load	190 boiler horse power
Minimum load	25 boiler horse power
Estimated fuel oil for boilers	375,000 gallons per year
Estimated sludge gas	4,972,500 cu. ft. per year

Steam Engine.—A vertical steam-engine driven generator unit, directly connected, will be installed to serve the dual purpose of reducing the 150 lb. per sq. in. steam from the boilers for use in the plant heating system, and to generate electrical energy. The output of this unit will be controlled by the low pressure steam demand, for plant heating system, and in case additional steam is required for this purpose, it will be supplied to the heating system by means of a pressure reducing station in the boiler house, which will cut in automatically.

Evaluation of Bids.—Bids for the steam driven generator were evaluated on the basis of performance, as between a steam engine generator and a steam turbine generator.

For the purpose of actual evaluation of bids a formula was devised in which the principal factors were:

1. Weighted steam flow, lb. per hour.
2. Fixed steam value, lb. per hour.
3. Cost value per hour.
4. Steam cost per year.
5. Cost differential on account of greater power output by a steam engine.
6. Ten year comparative cost.

The first cost of the steam engine generator was approximately $15,430 and with fixed charges at 6 per cent and maintenance cost at 1 per cent, the total annual cost is estimated at $1100 per year. It is estimated that 800,000 Kw.hr. will be generated per year at an estimated cost of $0.0056 per Kw.hr.

The engine will be a vertical, non-condensing type, designed to operate on saturated steam at 140 lb. per sq. in., with a back pressure of 6 lb. per sq. in. The generator will be an induction synchronous type of 200 Kw.

Costs

Out of a total cost of $11,000,000 for the treatment plant approximately $900,000 or 8.2 per cent will be expended for the incinerators, incinerator conveyors, ash handling system, gas holder and related equipment, gas engine generator, boilers, steam engine generator, and the necessary piping systems.

Conclusion

The author desires to acknowledge the assistance rendered in the preparation of this paper by the following engineers, who have taken an active part in the electrical and mechanical design features of the Detroit sewage treatment plant:

Mr. C. S. Lumley, Assistant Electrical Engineer (Electrical design—Lighting and Power).

Mr. P. M. Perkins, Assistant Mechanical Engineer (Mechanical design—Pumping Plant).

Mr. C. E. Rasmussen, Assistant Mechanical Engineer (Mechanical design—Power Plant).

Mr. I. J. Turnbull, Assistant Mechanical Engineer (Mechanical design—Heating and Ventilating).

STATUS OF SEWAGE TREATMENT IN THE CONNECTICUT RIVER VALLEY *

By Clarence I. Sterling, Jr.

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The pollution of the Connecticut River by domestic sewage and industrial waste has been a subject of discussion for a number of years, particularly by interests in the State of Connecticut. This river is the major stream within New England, having a total drainage area of 11,243 square miles of which 2,726 square miles are located within the State of Massachusetts. The river has a total length of 392 miles, its source being the Connecticut Lakes near the Canadian Border, discharging into coastal waters at Saybrook. Approximately 65 miles of the length of this river are within Massachusetts. The main tributaries of the stream within the State are the Deerfield, Millers, Chicopee and Westfield rivers. The population and drainage areas of these rivers are as follows:

	Population in State in 1935	Drainage Area in Square Miles	
		Within State	Total
Connecticut River	293,000	662	9,637†
Deerfield River	24,000	515	664
Millers River	46,000	311	391
Chicopee River	110,000	721	721
Westfield River	39,000	517	517
Total	512,000	2,726	

† At Thompsonville, Conn., near Connecticut State Line.

There are 26 municipalities within the State on the Connecticut River watershed having recognized municipal sewerage systems serving either a portion or the entire municipality. There are sewage treatment works at the present time serving the city of Gardner and the town of Winchendon on the Millers River watershed, while there is a sewage treatment plant in the town of Spencer on the Chicopee River watershed. These works consist of plain settling tanks and intermittent sand filters. In addition, the State institutions located within the Valley are all equipped with sewage treatment works of a similar type, with the exception of the Northampton State Hospital which discharges its sewage into the public sewerage system. The scope of this paper will cover particularly the municipalities in the immediate vicinity of the Connecticut River, which area is commonly known as the Connecticut River Valley but has more

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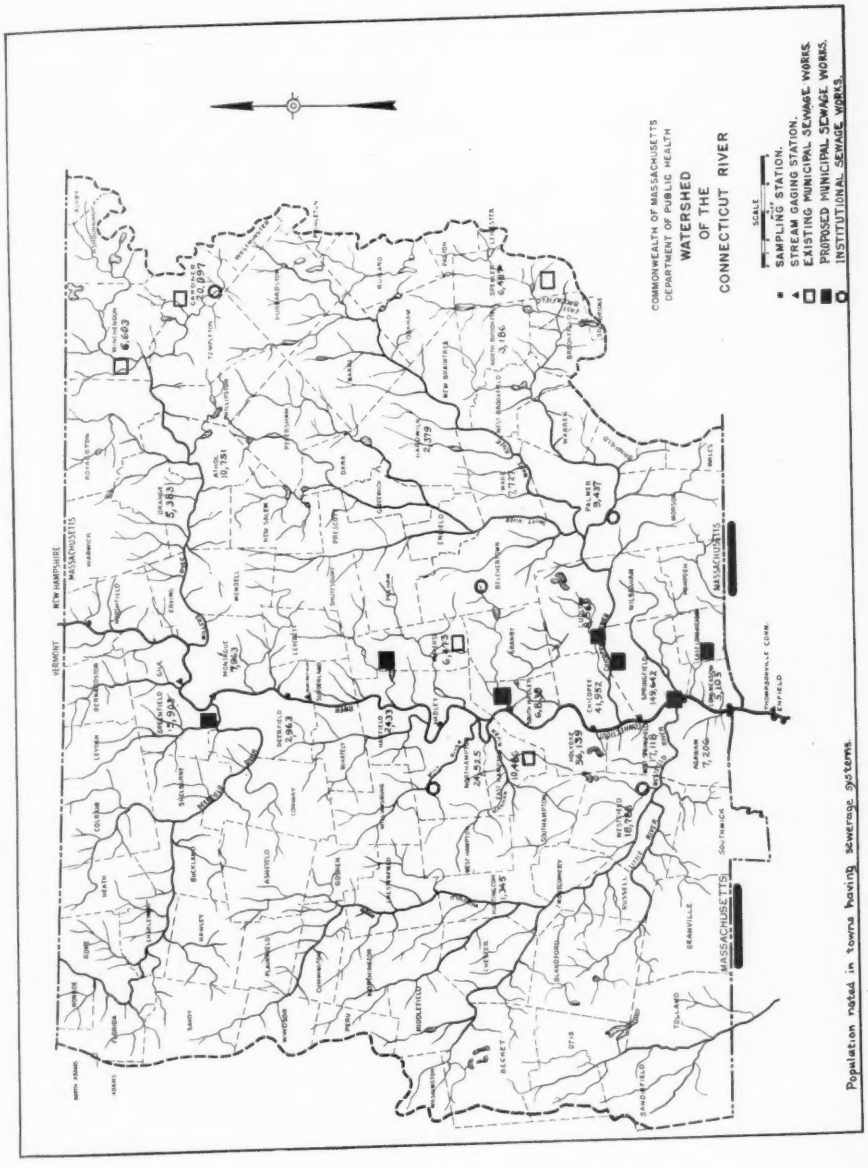
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC HEALTH
WATERSHED
OF THE
CONNECTICUT RIVER
SCALE
SAMPLING STATION.
STREAM GAGING STATION.
EXISTING MUNICIPAL SEWAGE WORKS.
PROPOSED MUNICIPAL SEWAGE WORKS.
INSTITUTIONAL SEWAGE WORKS.
Population noted in towns having sewerage systems.

recently been christened the Pioneer Valley. Here we have nearly the entire domestic sewage and industrial waste flows being discharged directly into the river without treatment.

While the supervision and general oversight of inland waters are powers delegated to the Massachusetts Department of Public Health, Section 168 of Chapter 111 of the General Laws specifically states that none of the regulations set up in the General Statutes for the prevention of stream pollution apply to either the Merrimack or Connecticut rivers. It is necessary, however, for a municipality to obtain the approval of the Department before any new sewer outlet can be located in a river. After sewage treatment works are once established the Department has the right to order additional treatment or improvements in the method of treatment if the works are operated in an inadequate fashion. The river enters the State from New Hampshire and Vermont, a relatively clean stream, and then receives the sewage and industrial wastes successively in its southerly course from Montague, Greenfield, Deerfield, Amherst, Hatfield, Northampton, Easthampton, South Hadley, Chicopee, West Springfield, Springfield, Agawam and Longmeadow. In addition, sewage is discharged by the town of Ludlow into the Chicopee River and by the city of Westfield into the Westfield River a short distance above the confluence of these rivers with the Connecticut River.

Of the above communities the town of Easthampton maintains a sewage treatment plant consisting of plain settling tanks and intermittent sand filters. The plant is inadequate and provides for primary treatment of only 75 per cent of the sewage in the settling tanks, with 15 per cent of the settled sewage receiving more complete treatment on the sand filters.

The town of Amherst at present maintains an intermittent sand filter plant for the treatment of the sewage from the easterly portion of the town, which constitutes about 20 per cent of the total sewage flow.

The river is not used for domestic water supply purposes and, while it is used to some extent for boating and fishing, the Department does not encourage bathing due to the discharge of untreated sewage into the stream. Many of the industries, however, utilize river water in their manufacturing processes. The volume of diluting water in this stream has always been sufficient to prevent a general nuisance condition although local nuisances often exist where the sewage is discharged onto the banks of the stream. Many of the outlets are of the submerged type, well within the channel of the stream. While no nuisance is ever observed where a submerged type of outlet is used, there is difficulty in maintaining a flow through these outlets due to silting in the outlet structure. The sewerage systems in the larger cities are generally of the combined type, and therefore present a problem in the treatment of sewage.

A recent study made by engineers employed on a W.P.A. Project under the sponsorship of this Department shows that approximately 60 million gallons of industrial waste are being discharged into this stream daily, a greater portion of which is from the paper industry. A summary of the industrial waste survey is shown in the following table:

City or Town	Kind of Manufactured Product, Process or Waste	Quantity of Industrial Waste (G.P.D.)
Montague	Paper, caustic soda, acid, laundry wastes	3,870,400
Greenfield	Cleansing, dyeing, laundry, metal plating, oakite, soda ash, oil, acid, bleach wastes, spent pickling liquor	95,400
Northampton	Sulphite paper mill waste	2,750,000
Easthampton	Cotton and rayon	9,200
South Hadley	Paper	2,402,000
Holyoke	Paper, de-inking waste, caustic soda, acid, dry cleaning and laundry wastes, worsted, cotton and rayon, paper coating wastes	39,809,000
Chicopee	Boiler blowoff, dye, caustic soda, oakite and acid wastes, brewery, soaps	2,208,000
West Springfield	Paper, oil burners, heavy machinery, dry cleaning and laundry wastes	2,088,000
Springfield	Dry cleaning, dyeing, and laundry waste, plating solutions, acid, caustic soda, soap and bleach wastes, oil, chemicals, salts	5,863,000
Agawam	Paper, woolen, dyes, soaps	892,000
Ludlow	Wash and dye wastes	108,000
Westfield	Plating solutions, laundry, paper, dyeing and textile wastes	774,500
	Total	60,869,500

The Department of Public Health collects monthly samples at various stations along the river during the period from June to November, inclusive. These samples are usually collected from bridges across the stream but the samples collected from the stations below the Holyoke Dam are collected from a motorboat. The amount of dissolved oxygen in the river has always appeared to be sufficient to prevent nuisances, while the B.O.D. of this stream is not excessively high. The results of the dissolved oxygen and biochemical oxygen demand determinations for the past two years are summarized as follows:

Year	Average D.O. in P.P.M.	Average B.O.D. in P.P.M.	Minimum Excess of D.O. over B.O.D. in P.P.M.
At Vermont-New Hampshire State Line			
1937	8.7	1.7	5.9
1938	8.3	1.7	4.1
At Connecticut State Line			
1937	6.3	1.5	2.8
1938	7.2	2.3	4.1

As stated before, the condition of the river has never been such as to result in a general nuisance condition with a demand for the treatment of sewage and industrial wastes. However, there is now an increased

demand for such treatment by various groups. This demand has been crystallized mainly by two factors; the policy of the Connecticut State Water Board in demanding treatment of the sewage in the municipalities along the river within the State of Connecticut, with the possibility of future litigation between the states, together with the demand for increased recreational facilities. During the past year plans have been approved by the Department for the construction of seven sewage treatment plants in the Connecticut Valley. This is rather remarkable due to the fact that there has been no compulsory legislation ordering the treatment of sewage. Each community installing sewage treatment works apparently has its own reason for doing so. At present the domestic sewage from 9,000 persons out of 385,482 persons residing in municipalities having public sewerage systems is being treated. With the completion of the above plants the sewage from 202,268 persons will be treated, together with the industrial wastes in those communities. The following table gives the population affected by the proposed treatment plants:

	Present Population (1935) Served by Sewers	Present Population with Sewage Treatment	Population to be Served When Present Construction is Completed
Montague	7,967	—	—
Greenfield	15,903	—	15,903
Deerfield	2,963	—	—
Amherst	6,473	1,400	6,473
Hatfield	2,433	—	—
Northampton	24,525	100	100
South Hadley	6,838	—	3,500
Easthampton	10,486	7,000	7,000
Holyoke	56,139	—	—
Chicopee	41,952	—	—
West Springfield	17,118	—	—
Springfield	149,642	—	149,642
Ludlow	8,569	—	8,569
Agawam	7,206	—	7,206
Westfield	18,788	500	500
Longmeadow	5,105	—	—
E. Longmeadow*	3,375	—	3,375
	385,482	9,000	202,268

* Has no sewerage system at present.

Springfield

Of course, the community of greatest interest would be the largest one, the city of Springfield. Here, with its population of approximately 150,000 persons, sewage is being discharged into both the Connecticut and Chicopee rivers through a large number of outlets. The city, along with other communities on the Connecticut River, has been seriously damaged by floods in the last three years and at present is engaged in an

extensive flood control project of diking and construction of drainage pumping stations. The Federal Government, in allotting aid for flood protection work, made an agreement with the city that if it advanced funds the city would install complete sewage treatment works within a period of five years. The period terminates in 1942.

Springfield plans to install two sewage treatment plants, one to serve the main portion of the city and the other to serve the so-called Indian Orchard section on the Chicopee River. It is planned to locate the main sewage treatment plant on Bondi's Island at the mouth of the Westfield River in the town of Agawam, across the Connecticut River from the city of Springfield. In order to convey all of the sewage from the various outlets, it was necessary to construct an intercepting sewer along the entire length of the Connecticut River in Springfield. This intercepting sewer, as designed, is capable of intercepting two times the dry weather sewage flow from an ultimate population of 274,500 persons. The main sewage treatment works, however, is being designed for a population of 190,000 persons with an average sewage flow of 30 million gallons per day.

Sewage treatment is to consist of the passage of the sewage through mechanically cleaned grit chambers, screening with comminution of the screenings, and sedimentation of the sewage in mechanically cleaned settling tanks. The effluent from the tanks will be returned to the river without further treatment through a submerged outlet. Sludge is to be digested in separate sludge digestion tanks equipped with floating covers, the digested sludge to be elutriated, conditioned with chemicals and dewatered upon vacuum filters. The filter cake is to be incinerated and the gas collected at the plant is to be utilized as fuel in the incinerator and for heating the buildings and digestion tanks. It will be necessary to construct a 15 foot dike around the plant for flood protection purposes.

The plant is to be similar to the Hartford, Connecticut, plant with the exception that the sludge will be incinerated instead of dumped, as at Hartford.

At the Indian Orchard plant the sewage will pass through the grit chambers and then through the screens, with comminution of the screenings. The sewage then enters the mechanically cleaned settling tanks, with the discharge of the settled sewage into the Chicopee River through a submerged outlet. The sludge at this plant will be digested and then dried upon covered sludge drying beds. The proposed plant has a design capacity of 3 million gallons per day to treat an estimated dry weather sewage flow of 1.5 million gallons per day from a population of 10,000 persons. In addition, it provides for the treatment of 1.5 million gallons per day of industrial wastes, which is an equivalent population of 10,000 persons.

Here again it is necessary for the city to construct a trunk sewer to intercept the sewage now being discharged into the Chicopee River from the various outlets and convey it to the treatment plant site.

The designed features for both Springfield treatment plants are as follows:

	Main Plant	Indian Orchard Plant
Designed Capacity M.G.D.	30	3
Designed Population	190,000	20,000*
Type of Sewers	Combined	Combined
Trash Racks	3 in. openings	3 in. openings
Grit Chambers	2	2
Capacity, M.G.D. (each)	15–61.75	0.8–2.5
Detention Period, sec.	35	50
Velocities, ft./sec.	0.41–1.2	0.5–1.0
Cleaned	Mechanically	Hand
Screening	3 Comminutors	2 Comminutors
Settling Tanks	4	2
Size, feet	50 × 115	16 × 87
Depth of Sewage, feet	14.5	12
Capacity of each, gals.	625,000	125,000
Detention Period, hrs.	2	2
Cleaned	Mechanically	Mechanically
Sludge Digestors	4	2
Type	Floating cover heated	Floating cover heated
Capacity, cu.ft./cap.	1.0	1.35
Sludge Drying	Elutriation-vac. filters	Covered drying beds
Area, sq.ft./cap.	—	0.5
Sludge Disposal	Incineration	Fill
Chlorination	Provisions made for installation	
Designed by	Gascoigne & Associates	

* Includes 10,000 equivalent population for industrial wastes.

The contract for these intercepting sewers was recently let, while the contract for the main treatment plant will be advertised for bids within the month. The estimated cost of the entire work, including the intercepting sewers and both sewage treatment plants is $2,700,000, the work to be done under a P.W.A. Project.

Ludlow

The town of Ludlow is installing at the present time a sewage treatment works capable of treating the sewage from a population of 7,000 persons. The sewerage system in this town is of the combined type, with the sewage being discharged into the river through three outlets. The industrial waste from the principal industry in the town of Ludlow, the manufacturing plant of Ludlow Associates, is discharged into the public sewerage system. Work was started under a W.P.A. Project for the construction of the intercepting sewers, a sewage pumping station, and treatment works for the complete treatment of all domestic sewage and industrial wastes in this town. The intercepting sewers and pumping station have been completed and the treatment plant is under construction at the present time.

The plant is designed for the treatment of two times the dry weather sewage flow. The sewage will pass through a manually cleaned screen and grit chamber into a pre-aeration tank, thence into mechanically cleaned settling tanks, with the settled sewage being discharged into a chlorine contact tank, thence into the Chicopee River. The sludge will

be digested and dried upon a covered sludge drying bed. Provisions are being made for the future construction of an incinerator to be used at the sewage treatment plant site for the incineration of the dried sludge, garbage and rubbish. The work is being done under a W.P.A. project at an estimated cost of $27,300 for intercepting sewers and pumping station and $69,200 for the treatment plant.

The principal design features of this plant are as follows:

Design Capacity, M.G.D.	0.9
Design Population	7,000
Type of Sewers	Combined
Screening	Manual, 1¼ in. clear spacing, shredded
Grit Chambers	2
Capacity (each), M.G.D.	0.9
Detention Period, seconds	60
Velocity, feet/sec.	1
Cleaned	Hand
Pre-Aeration Tank:	
Detention Period, hours	0.5
Air, cu.ft./gal.	0.1
Settling Tanks	2
Detention Period, hours	2
Cleaned	Mechanically
Sludge Digestors	2
Type	Heated
Capacity, cu.ft./cap.	2
Sludge Drying:	Covered drying beds
Area, sq. ft./cap.	0.5
Chlorine Contact Tank	1
Detention Period, minutes	30
Designed by	Henry W. Taylor

East Longmeadow

The town of East Longmeadow, having a population in 1935 of 3,375 persons, has obtained a W.P.A. Project for the installation of a complete sewerage system to serve the populated area of the town, together with sewage treatment works. At the present time the sewers are being installed, while the final plans for the sewage treatment works were recently approved by the Department. The town of East Longmeadow does not border directly on the Connecticut River or any other large stream. It is, therefore, necessary to have complete treatment of the sewage. The treated sewage will be discharged into a small brook passing through the Franconia Golf Course, a municipal course, and Forest Park, in the city of Springfield, before entering the Connecticut River. The treatment plant will have a designed capacity of 380,000 gallons per day and will serve an estimated future population of 4,300 persons. The sewerage system is of the separate type.

Treatment will consist of the passage of sewage through a manually cleaned screen, and with sedimentation in a two-story sedimentation tank. This tank will have two settling compartments, and a single digestion compartment. The settled sewage will flow into a dosing tank

and then discharge upon a glass-covered trickling filter, with distribution of the settled sewage by means of spray nozzles. The effluent then flows into a secondary settling tank of the hopper-bottom type, the effluent from which will be chlorinated and retained in the chlorine contact tank before being discharged into Pecowsic Brook. Sludge from the secondary tank will be pumped to the middle compartment of the Imhoff tank from where the digested sludge will be withdrawn hydraulically onto a glass-covered sludge drying bed.

The estimated cost for the entire sewerage project is $325,000, with the treatment works costing $70,000.

The principal design features of this plant are as follows:

Design Capacity, M.G.D.	0.38
Design Population	4,300
Type of Sewers	Separate
Screen	Hand cleaned bars spaced 2 in. on centers
Settling Tanks	1
Type: Imhoff tank	2 settling compartments and 1 digestion compartment
Size: (Settling), feet	50 by 10 by 7 (Depth)
Size: (Digestion), feet	50 by 15¾
Total Depth of Tank, feet	21.53
Detention Period, hrs.	2.1
Sludge Storage, cu.ft./cap.	2.0
Trickling Filter	
Type	Covered, nozzle distribution
Rate of Filtration, M.G.A.D.	3.0
Depth, feet	7.0
Secondary Tank	1
Type	Hopper bottom, covered
Capacity, gallons	125,000
Detention Period, hours	0.8
Chlorine Contact Tank	1
Detention Period, minutes	11.5
Sludge Drying	Covered drying bed
Area, sq.ft./cap.	0.32
Designed by	Tighe and Bond

Amherst

As stated before, the town of Amherst has some sand filters which treat a portion of the sewage from the easterly portion of the town. The other 80 per cent of the sewage is conveyed by gravity in a long sewer to the Connecticut River at North Hadley. As the present works are inadequate, the Department has recommended the abandonment of the present treatment plant and pumping the sewage to the westerly district where it will be treated before being discharged into the Connecticut River. This recommendation is being carried out. It was deemed advisable to discharge the sewage into the Connecticut River as it would necessitate only primary treatment of the sewage.

The sewerage system of the town of Amherst is of the separate type. Heretofore there has been considerable trouble from groundwater leakage together with cellar and roof drainage from the various houses. Under

the present project considerable money is being spent on re-laying some of the trunk sewers to reduce infiltration of ground water into the sewerage system. The proposed plant will consist of two grit chambers with screening and comminuting of the screenings, sedimentation in mechanically cleaned settling tanks, with the pumping of the settled sewage back into the trunk sewer to the Connecticut River. The sludge will be digested in two heated sludge digestion tanks of the floating cover type and dried upon one covered and two open sludge drying beds.

The design features of the plant are as follows:

Design Capacity M.G.D.	1.0
Design Population	8,000
Type of Sewers	Separate
Grit Chambers	2 Manually cleaned
Screening	1 Comminutor
Settling Tanks	2
Size, feet	46 by 15
Depth of Sewage, feet	8
Capacity of each, gals.	42,000
Detention Period, hours	2
Cleaned	Mechanically
Sludge Digestors	2
Type	Floating covers, heated
Capacity, cu.ft./cap.	2.25
Sludge Drying	1 covered and 2 open drying beds
Area, sq.ft./cap.	0.75
Sludge Disposal	Fill
Designed by	Frank A. Barbour

The contract price for the sewage treatment works is about $83,000, while the total cost of the work is about $160,000. Work upon the pumping station and trunk sewers is nearly completed and the treatment plant is now under construction and should be completed by autumn.

Greenfield

At the present time the town of Greenfield is constructing a sewage treatment plant for the treatment of sewage and industrial waste in the town. This plant is to serve an estimated population of 20,000 persons and will have a design capacity of 2.0 million gallons per day. The sewerage system in this town is of the separate type. Due to the competent planning of the sewerage system it was necessary to lay only a short section of intercepting sewer to convey the sewage to the treatment works, now under construction. Treatment will consist of screening and comminuting of the screenings, sedimentation in covered mechanically cleaned settling tanks, with the effluent being discharged directly into the Green River, a tributary of the Deerfield River. The sludge will be pumped into a fixed-roof sludge digestion tank, while an open tank of similar capacity will be provided for sludge storage. The sludge will be dried upon open sludge drying beds.

The plant is being built under a P.W.A. Project at a contract price of $92,000. It is necessary to construct a short section of sewer to connect the plant to the sewerage system. This is being done under a

W.P.A. Project at an estimated cost of $12,800. The plant should be completed and in operation by the end of the summer.

The principal design features of this plant are as follows:

Design Capacity, M.G.D.	2
Design Population	20,000
Type of Sewers	Separate
Screening	2 Comminutors
Settling Tanks	2 Covered
Size, feet	70 by 16
Depth of Sewage, feet	10
Capacity of each, gals.	84,000
Detention Period, hours	2
Cleaned	Mechanically
Sludge Digestors	1 Digestor and 1 storage tank
Type	Fixed roof, heated
Capacity, cu.ft./cap.	2.0
Sludge Drying	Covered drying beds
Area, sq.ft./cap.	0.75
Sludge Disposal	Fill
Designed by	Metcalf and Eddy

Agawam

The town of Agawam cooperated with Springfield in not opposing legislation which the city of Springfield needed for locating their sewage treatment plant in that town. As a result, Springfield has agreed to treat the sewage from the town of Agawam in lieu of paying taxes upon the treatment plant site. As a result, Agawam has recently had a complete engineering study made for the construction of intercepting sewers. They will intercept the sewage from the present sewer outlets now discharging into both the Westfield and Connecticut rivers and carry this sewage to the main sewage treatment plant of the city of Springfield. It is anticipated that this work will be carried out under a W.P.A. Project at an estimated cost of $500,000.

South Hadley

There is one other sewage treatment plant which might be said to be in the primary form at this time, and that is the proposed plant for treating the sewage and industrial wastes in the village of South Hadley Center in the town of South Hadley. At the present time this sewage is discharged directly into Bachelor Brook, a tributary of the Connecticut River. Recently the town endeavored to obtain a W.P.A. Project for the extension of their sewerage system but this was refused on the ground that the dumping of an increased amount of sewage into a small brook would aggravate the present conditions. Therefore, the town has engaged the services of a consulting engineer for the construction of sewage treatment works to serve this portion of the town. The preliminary plans for the works call for installation of mechanically cleaned screens, mechanically cleaned settling tanks and separate sludge digestion, with the drying of the sludge on open sludge drying beds, and with the possible carrying

of the effluent from the plant in a pipe line directly to the Connecticut River where a larger amount of diluting water is available.

Other Municipalities

While there has been considerable talk in many of the other municipalities along the river relative to sewage disposal, at the present time there is little evidence of action by these municipalities. The city of Holyoke, however, is constructing at the present time under a W.P.A. Project the northerly portion of the intercepting sewer for the ultimate conveying of all the sewage to a central treatment site. In both the cities of Holyoke and Chicopee the problem of sewage disposal is financially a very serious one. This is due to curtailed industrial activity and, in the latter case, the straitened financial condition of the town, as well as the expense of the construction of long intercepting sewers and a sewage treatment works. It is, however, gratifying to see some of the municipalities undertaking this work without compulsory legislation. The writer is sure that the results will justify the present expenditure of money and the remaining communities will soon keep pace with the leaders.

OBSERVATIONS ON OPERATION OF INSTITUTIONAL SEWAGE TREATMENT PLANTS *

By J. Henry L. Giles

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Connecticut has developed a policy of building state institutional sewage treatment plants as examples for municipalities and industrial corporations along her many streams. These plants were designed to give at least the treatment needed for all sewage outlets on each stream. At present, there are twelve major state institutional plants in Connecticut, and another ten plants of the institutional type that are covered by this paper.

Operators.—It has been said, and will bear repeating at this time, that a good operator can obtain better results from a poor or mediocre plant than a careless, disinterested operator can get from a good plant.

The operating personnel at Connecticut's institutional sewage treatment plants is of a variable kind. In some cases, the plants are in charge of full-time operators who have personal interest in the plant operation. In other instances, part-time men do a good job. At three institutions, the subordinate operators are patients. All plants are supervised by the institution's chief engineer and are visited at regular intervals by a sanitary engineer of the State Department of Health, in order to encourage efficient operation. At all of these institutional plants, operation is satisfactory and the men take a personal interest in the plant and grounds.

Treatment Plants.—The sewage treatment plants at these institutions include septic tanks, Imhoff tanks, plain sedimentation with gravity sludge removal, plain sedimentation with sludge pumps, plain sedimentation with mechanical scraping mechanisms, various types of separate sludge digestion tanks, sand filters and chlorination.

Flows.—All institutions were supposedly on a separate system, but from time to time the institutional engineers have located roof drains, catch basins and other unnecessary clear water connections to the sewer, and have eliminated them in order to reduce storm flows. One institution is considering a project of laying new sanitary sewers in order to eliminate storm water connections, made many years ago.

Sewage treatment plants at these institutions serve from 100 to 4,000 persons. These populations contribute flows of 10,000 gallons per day to 0.75 m.g.d. The sewage at all institutions is strong, varying from 100 to 440 p.p.m. suspended solids and from 110 to 630 p.p.m., B.O.D., which are yearly averages for day flows.

Laundry wastes have been especially difficult to handle at times, as they result in high flows and turbid effluents. At one institution, which handles laundry for several institutions, a chemical precipitation treatment plant was provided for the laundry wastes. The wastes are treated with

* Presented at the Tenth Anniversary Spring Meeting of the New England Sewage Works Association, West Springfield, Mass., May 15, 1939.

calcium chloride, alum and lime, flocculated, settled for two or more hours, and then discharged to the sand filters.

Kitchen wastes, including large quantities of grease, have been a problem at several plants. Grease collects and plugs the sewers of small buildings. At drop manholes, it is aerated, de-emulsified and collects in large quantities wherever the flow is stilled. Grease collects on the surface of the flow compartments of settling tanks and makes the job of skimming a never-ending one. Grease coats other solids and prevents them from settling, or increases scum in gas vents or digestion tanks.

Rags are another major problem at the insane hospitals. Aside from the usual run of rags which the ordinary operator has to contend with, stockings, underwear, suits and dresses, and even sheets somehow or other reach the treatment plant, resulting in plugged sewers, over-flowing raw sewage and complete plugging of hand-cleaned bar screens. Large stringy rags go through the screens and result in heavier scum in gas vents or digestion tanks.

The only other waste encountered that has given difficulty with operation is sodium thio or hypo-sulphate (photographers' "hypo") at institutions doing x-ray work. This "hypo" in moderate quantities has been found to reduce the chlorine residuals for several hours. A separate dry well or connection to a storm drain has been the only solution for this problem.

At two institutions, pumping is required. At one, the entire flow is pumped to the sedimentation units with post-chlorination. When this plant was first placed into operation, peak pumping periods caused some difficulties in adjustment of chlorine dosage and also disturbed sedimentation efficiency. This condition was improved greatly by making adjustments so that the pump operating period was reduced to one minute.

Flow Measurement.—All institutional treatment plants are now equipped with some form of flow measuring device. Several plants with dosing tanks have counters installed and continuous record of discharges is made. At the remaining plants, 8-in. or 12-in. weirs in effluent channels are used, and regular or high flow readings are recorded.

Measurement of the flow over several years has been useful in planning extensions to present plants, and in estimating chlorine needs. Flow rates have been recorded from one-fourth the normal flow to five times the normal flow, the latter indicating need for providing capacity for peak flows. Average per capita flows vary from 75 to 200 gal. per capita per day. The higher figure is now basic design for sanatoria and insane hospitals.

Sewers.—The sewers at all institutions have been designed large enough for flows encountered. Manholes, however, have been built at some institutions without channels through them. Some lines would have been improved if manholes had been installed at 200 to 300 ft. intervals and at all changes of direction. Cast iron pipe with leaded joints along streams and in locations with high ground water, and properly made joints at other places, would have helped in reducing flows. Sewers of

cast iron on excessively steep grades would help in avoiding washouts which have been experienced at two institutions.

Screens and Grit Chambers.—No mechanically cleaned bar screens have been provided and only one mechanically cleaned grit chamber has been built at these institutional plants. In several cases, mechanical equipment would be helpful where rags are excessive and full-time operation cannot reasonably be expected.

In most cases, the bar screen and grit chamber are built as one unit. Some trouble has been experienced at some of the smaller plants because of an oversize preliminary unit provided. The preliminary unit has acted as a septic tank, which caused difficulty until the cross sections were reduced to one-third or one-fourth the original size by filling in with concrete or using planks enclosing sand fill.

Two or more grit chambers with some means of controlling depth of flows are desirable at institutions with wide variation in flows, in order to reduce organic accumulations and to permit effective removal of the considerable amounts of grit received even at plants supposedly connected to a separate system.

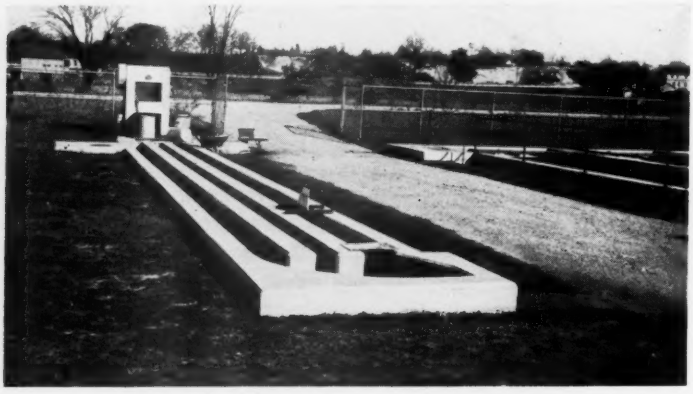

FIG. 1.—Grit chambers at Putnam, Conn. Mechanical bar screen in distance. Type advocated for state institutional sewage treatment plants.

At one plant, where a mechanically cleaned grit chamber is provided, a bar screen chamber ahead of the grit chamber receives most of the heaviest grit because of a concrete obstruction back of the screen. Screen chambers with flat bottoms or very slight slope will pass grit and make a more effective screen area.

The screens at one plant were removed each year during the vacation of the regular operator, in order to eliminate the necessity of cleaning several times daily. This practice results in large objects getting into the tanks, clogging valves, and making the handling of scum and sludge more difficult. At another plant, not originally provided with a bar screen, a single screen of four bars in a narrow grit chamber has aided in reducing the number of rags handled in the tanks.

Sedimentation Tanks

Septic Tanks.—Septic tanks have been built for several institutions which house 100 to 1,100 persons. These tanks have given good overall efficiencies and in many cases the cost of operation has been small. The principal difficulties have been the removal of scum, poor digestion, and the removal of solids from tanks provided with riser pipes.

The following points are suggested as aids in operation where septic tanks are already installed or are being designed.

1. Bottom draw-offs for all sludge and scum should be provided or a sludge pump of good capacity and adequate suction lift is needed to clean out the tanks periodically.

2. Scum draw-offs are helpful where scum can be floated off by raising the liquid level in the tank.

3. Two or three tanks are desirable so one tank can be digesting while another tank is in use.

4. If two or three tanks are available, it might be better to operate one as a digestion tank and the others as plain settling units. This has been done at one institution and plans are being considered for this operation at another location.

5. When a tank is taken out of operation, it is desirable to wet down, plunge or flood the scum so as to break up the dried solids to aid digestion. At two of our small municipal sewage treatment plants seed sludge from a tank to be emptied is pumped to a tank being digested, with favorable results. So far, this practice has not been followed at any state institution because of lack of necessary pumping facilities

Plain Sedimentation Tanks.—Plain sedimentation tanks are used at three institutions and are planned for a new institution now being built. At one institution, two tanks are equipped with mechanical scrapers. The operator at these plants can view the sludge he is removing by observation of the discharge pipe into the digestion tank.

It has been found necessary to draw sludge once daily during the summer months. If two or three withdrawals weekly are used, especially during the summer, excessive scum accumulates on the surface of the settling tanks and the plant effluent shows more solids.

With good operation, there appears to be little advantage of one type unit as compared with the other. All have operated efficiently, even with flows well over the design capacities, giving detention periods as low as one hour. For normal flows, two to three hours detention is provided.

Daily skimming of settling tanks is practiced at all except one plant, where the tanks are covered and here the tanks are skimmed twice weekly with satisfactory results. Fortunately, we have two tanks at each plant so the tank being skimmed is removed from operation for one to two hours after the skimming is completed to avoid escape of solids in the effluent.

Imhoff Tanks.—Imhoff tanks have been built for six institutions. Detentions of two to three hours for design flows have been provided. All these plants are giving good efficiencies in solids removal, even with flows in excess of that for which they were designed. Four institutions

have two flowing-through compartments per tank, the others have only one. Three institutions have only one tank each, with two flowing-through compartments.

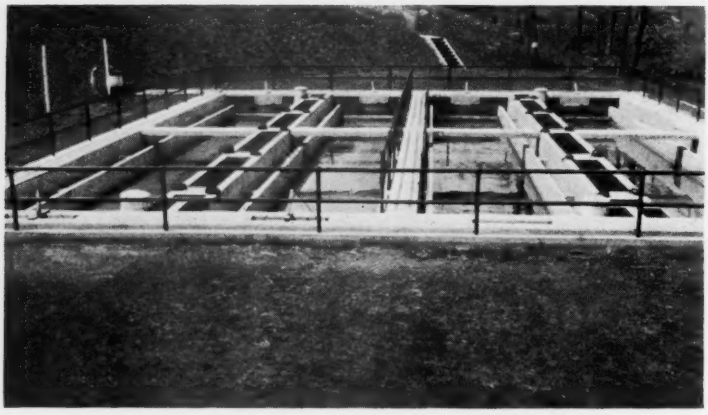

FIG. 2.—Imhoff tanks at Fairfield State Hospital, Newtown.

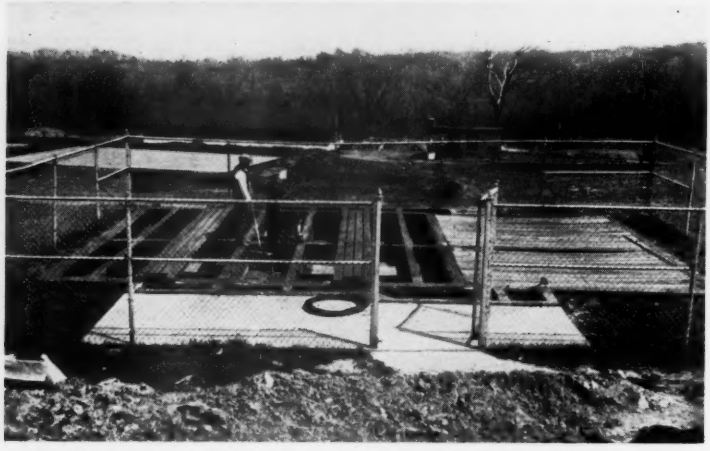

FIG. 3.—Imhoff tank at Cedarcrest Sanatorium, Newington, Conn. Dosing chamber and filters beyond are shown.

In all cases, flexibility in operation is sufficient to permit removal of one flowing-through compartment from use while it is being skimmed. Best results are obtained if only one flowing-through compartment is cleaned daily, as only greasy material floats on the surface and the two to three days' accumulation solidifies and is more easily removed. A floating beam the width of the flowing-through compartment, moved from the outlet baffle to the inlet baffle, collects the grease so it can be more readily removed by a skimmer than by attempting to hand-skim the entire surface.

The aprons of flowing-through compartments are squeegeed and the slots are chained at weekly intervals. Fortunately, no triangular beam slots have been provided at these plants, so no trouble has been experienced with clogged slots except during the breaking-in period, when undigested solids have risen en masse to the slots and had to be broken.

So far, sludge storage has been adequate in all these Imhoff tanks, and regular liming at the rate of 50 pounds of lime per 1,000 persons per week has kept a pH value of 6.6 to 6.8 in the supernatant liquor and approximately 7.0 in the digested sludge. The sludge level is kept generally 2 to 4 ft. below the slots so as to maintain as large proportion as possible of digested sludge in the tank. Sludge is drawn once each month at three institutional plants and every two or three months at the rest.

During the summer, while digestion is progressing at a rapid rate, it has been found best to keep the sludge level down 3 or 4 ft. from the slots in order to avoid digested solids rising in the flowing-through compartments. During the winter or early spring, however, the sludge level 2 ft. below the slots has not given trouble.

At one plant, monthly records of temperatures in the digestion compartment of the Imhoff tanks have been kept for several years. During the summer, temperatures have gone as high as 76° to 78° F. and during the winter, temperatures have not dropped below 62° F. This institution does all of its own laundering and the high flows of warm sewage during the winter probably account for this favorable temperature range.

One experience worth mentioning, that has occurred at several plants at least once, is that if regular liming during the winter and spring months is carried out, foaming in the gas vents during the late spring or early summer months occurs as the rate of digestion increases. Foaming has been prevented at all plants the last few years by reducing the amount of lime added to one-half, or stopping it altogether during March and April.

At those plants where we have tried to discontinue liming, acid conditions have resulted, and pH values of 6.0 to 6.2 were noted. These lower pH values were accompanied by increased scum in the gas vents and the sludge has not been well digested. It is believed that the large amount of carbonaceous material in the form of paper received at institutional plants is responsible for the need of continuous liming. It has been said that laundry wastes raise the pH value in the digestion compartments of Imhoff tanks. This has not been our experience in Connecticut with institutional plants.

No scum accumulation is found in the gas vents of any of our state institutions today. Regular plunging of the light scum, lime additions and removal of small quantities of sticks, rags and grease are probably responsible for this favorable condition.

Hosing of scum in gas vents has been discontinued at all these plants because the large amount of water required forces some solids up in the flowing-through compartment. Plunging does not appear to give this trouble.

At one plant, two years after it was started, trouble was experienced with a foamy scum. The cause was apparently a reduction of lime, for exeessive liming for several months resulted in a pH over 7.6. The foaming scum was removed and buried and the pH allowed to drop to 7.0 before more lime was added, and no appreciable scum has been noted since.

Digestion Tanks.—There are separate sludge digestion tanks at the three institutions with plain sedimentation. These tanks are all rectangular and have liquid depths below the overflow, of 7 to 10 feet. They have sludge capacities of 2.5 to 3 cu. ft. per capita and are generally satisfactory in producing a well digested sludge. None of these tanks is heated.

FIG. 4.—Sedimentation and digestion tanks at Connecticut State College, Mansfield, Conn. Screen and grit chamber in foreground. Dosing tanks in background.

The tank at one plant has a fixed cover and is made up of three parallel sections, with openings at the ends so as to give the sludge a long travel. Apparently the travel is too long as the sludge is watery and the scum accumulates to excessive depths at the inlet of the first section. The only method devised so far to control the scum has been to remove all scum in that compartment at yearly intervals. This work is done by patient labor so costs are not a consideration. Recently, a connection to the sludge pump was made for using supernatant liquor for hosing the scum. The use of tap water caused excessive overflow, waste of water and higher lime requirements.

At the other two plants, all scum is plunged regularly and rarely are more than 3 or 4 in. of scum noted. Dry lime is added directly to scum and is mixed by plunging. Lime additions required in these tanks, as well as in Imhoff tanks, approaches 50 lb. per 1,000 population per week. pH values of 7.0 for the digested sludge are maintained with slight variations.

At two of these plants, digested sludge is pumped to the inlet of the digestion tank while raw sludge is being drawn from the settling tanks,

to provide better mixing. This procedure is not possible at the third plant.

Two to three feet of supernatant liquor is usually maintained. Less than this amount results in excessive solids in the overflow; more than this reduces the sludge storage capacity too much. Deeper tanks would permit greater supernatant liquor depths and correspondingly better overflow liquor.

Overflow liquor is pumped back to the raw sewage at two plants, and at the third it is drawn off to a sludge bed with satisfactory results.

Stage digestion is not practiced at any state institution, but at one private school of 500 persons, stage digestion works very well, though pH values are generally high in the second stage tanks even though lime is added only to the first stage tanks.

Dosing Tanks.—Dosing tanks are provided at the six plants with sand filters. Alternating siphons are provided at all but two of these plants. Very little trouble is experienced with these units if the tanks and siphons are cleaned at least monthly. Accumulated scum on the sides of the tank is brushed or hosed off and the lines of the siphon are flushed out. Occasionally, the bells of the siphons are lifted off and these units are completely cleaned.

FIG. 5.—Sand filters at Fairfield State Hospital, Newtown.

Sand Filters.—Sand filters are provided at six state institutions that are located near small streams. These filters are built with 30 to 36 in. of washed sand of 0.3 to 0.5 mm. effective size, and a uniformity coefficient not exceeding 3.5. They have been so designed that a dose of the siphon chamber covers the bed 2 to 3 in. deep. Except at times of excessive flows, these beds will dry at the surface before the next discharge occurs.

The number of sand filter units at the individual plants varies from four to twelve. Operating practice, generally, is to use only one filter each day and then shut it off, using beds in rotation and resting the units between dosings. Exceptions may have to be made at times of heavy

flows. Vents from the under-drains through the filter surfaces are provided at only one plant. They have not appeared to be necessary and are subject to the disadvantage that overflows may occur through them.

Only one institutional filter plant has a by-pass around the filters. This by-pass had to be used when floods caused the receiving stream to rise to such an elevation that the sand filters have been completely flooded. It is desirable to seal filter by-passes.

At four plants, the filter surface is harrowed to a depth of ½ to ¾ in. weekly, to once monthly, to keep the top crust broken. Once in three to five years, the top 1 or 2 in. of dirty sand is removed. Every second or third cleaning is followed by replacing 6 in. of clean sand. At two plants, regular scraping of dried sludge from the surface has been all that was necessary for several years. However, during recent construction of new buildings, so much drainage from the cellars was allowed to reach the plant that the fine clay accompanying the drainage and not removed by the tanks clogged the surface of the beds so completely that it was necessary to clean off 2 in. of sand twice in six months. Excessive grease in the warm sewage of the other plant caused the clogging of several filters at that plant, so at all plants some sand has been removed from the filters.

No deep cultivating of the sand surface is permitted because experience with several municipal plants indicated that sewage solids only reached deeper into the sand and eventually caused more sand to be removed.

No furrowing of the surface of the filters has been found necessary for winter operation. If ice forms, the next few doses of sewage will usually melt it. Furrowing also may cause solids to penetrate the sand to excessive depths.

Weeds grow on the surface of filters during the summer. Regular shallow harrowing and hand pulling appear to be the most effective methods of removing the growths. It has been reported that chemical weed killers or burning have been fairly effective but the institutions have preferred the more positive hand operation.

Chlorination.—Pre-chlorination is used at two Imhoff plants and one septic tank plant. Post-chlorination is used with one plain sedimentation tank. Complete disinfection of the sewage has been possible at all times except when thiosulfate (hypo) solutions were discharged to the sewage. The flows at these plants are normally low so that excessive chlorine residuals are maintained most of the time in order to cover brief peak flows. Frequent changing of the chlorine dose has not been practical.

An attempt is made to maintain 0.2 p.p.m. residual chlorine during high flows, so at other times tests as high as 2.0 p.p.m. may be noted. For the septic tank plant, a 2-lb. per day rate of chlorine application takes care of flows of 10,000 g.p.d. At the other plants, dosages of 10 lb. per day are used for 0.1 m.g.d.

Sludge Drying Beds.—Four institutions are provided with glass-covered sludge beds, primarily for odor control. The others have open sludge drying beds. All have worked satisfactorily. Sand depths on these beds

vary from six inches to two feet of washed sand, with the same specifications as for sand filters. At only one plant was a single open sludge bed provided and another bed is now under construction at this plant.

Sludge is drawn once each month at two of the larger plants and drawings vary from two to six months at the other institutions, which have adequate sludge storage. Sludge is drawn to depths of 3 to 8 in. on these sludge beds.

The drying period for sludge at all these plants varies from six days to a month, depending on the depth of sludge drawn and the weather. The sludge could be removed sooner than it is in many cases as the operator usually puts off cleaning the bed until he can get help, and the institutional farmer rates sludge removal at the last in the importance of his duties.

Sludge, Grit and Screenings Disposal.—Grit and screenings are disposed of by burial at all institutions. Trenches are dug in the vicinity and filled in layer by layer until a foot from the top. Then another trench is located. At a few institutions, grit and screenings are removed in barrels and buried at another location.

The dried sludge is used as a soil conditioner. It is usually composted with grass and allowed to decompose over one winter, then it is taken and spread around shrubs or lawns. None is used on crops as yet, though it has been approved for corn fields or other crops that grow out of the ground and are not eaten raw.

Tests and Records.—Field tests at all institutional plants are limited to the Imhoff cone tests for settleable solids, to guide the operator on tank efficiencies, residual chlorine tests, and pH tests at some plants for control of digestion tanks. Composite samples are collected at approximately three-month intervals by a representative of the State Health Department for a record of actual plant efficiencies.

Weekly record sheets for daily records are kept at all plants, for summarizing the work done. These records include flows, screenings and sludge removals, settleable solids, chlorine residuals and pH tests, chemicals used and units in operation or on which work was being done.

Industrial Wastes

THE DISPOSAL OF INDUSTRIAL WASTES *

By F. W. Mohlman

Director of Laboratories, The Sanitary District of Chicago

It is unfortunate that most types of industry produce wastes which, when discharged untreated, pollute streams, overload sewage treatment works, or produce tastes and odors in water supplies. Some industries, of the so-called "dry" type, are free from the incubus of liquid wastes, but the waste-producing industries are just as important in our national economy as the dry industries. However, the difficulty seems to be that the wet industries have not recognized that the cost of proper disposal of their wastes must be reckoned in with other legitimate items of operating expense, and now as the demand for clean streams, unpolluted water supplies, and treatment of industrial wastes becomes more insistent, such manufacturers find themselves faced with an expense that they have failed to reckon with in their past budgets.

Why do such excellent research organizations as the laboratories of the Institute of American Meat Packers, the Institute of Paper Chemistry, and the Brewers Industrial Foundation avoid the problem of waste disposal, which should be one of their major lines of investigation? It is of course because the industries have found it cheaper to temporize and follow a policy of passive resistance to the expenditure of money for waste disposal, and the research laboratories are therefore not permitted to include this problem in their curricula.

Again, how few are the endowed research fellowships in our universities on the problems of industrial waste disposal. The subject is painful to industrial executives, most of whom claim that their profits depend upon prevention of losses in their wastes, whereas those who have investigated industrial wastes know that the manufacturer rarely appreciates how much of his product goes down the sewer until a reliable sampling and gaging survey is made in cooperation with some public engineering bureau. After such surveys, however, the problem of treatment of irreducible losses usually remains, and the solution of such problems is expensive. Nevertheless, this expense is a legitimate part of the operating budget. If surveys, plans and provision of funds for disposal of wastes had been made when the factory started operation, such expenditures would have been considered a necessary part of costs of operation. It has been a short-sighted policy of industry in general to temporize on this problem, and to fail to accept the responsibility for satisfactory disposal of wastes.

* Presented at the Annual Meeting of the Michigan Engineering Society, Kalamazoo, Michigan, April 14, 1939.

Discharge of Wastes

Industrial wastes fall into two classes—those that are produced in the city and are discharged into city sewers, and those that are produced outside of cities and are discharged with only the sanitary sewage of the employees. In the latter case the problem of treatment falls entirely on the manufacturer and usually he is faced with a more difficult and more expensive project than is faced by an identical plant located in the city. It is usually true that the disposal of industrial wastes in a sewage treatment plant is cheaper than disposal alone, although this may not be true if the industrial waste population equivalent greatly exceeds the human population tributary to the treatment works.

The city factory therefore usually gets off easy in its waste-disposal problem. Most of our city industries pay only taxes as their contribution toward the treatment of sewage, but on this basis the dry industries pay equally with the wet industries, therefore the latter by no means assume equitable responsibility for the burden they place on the municipal budget. When a wet industry outside of the city must spend money on waste treatment, it must shoulder the expense alone—as witness the admirable waste disposal plant of the Dow Chemical Company at Midland, Michigan. Why should the city industry evade like responsibility?

Basis of Charge

Where sewer rental ordinances are in effect in the United States, the charge for treatment of industrial wastes is usually based on volume alone. Although sometimes a clause is inserted in the ordinance which provides for a surcharge based on solids or biochemical oxygen demand, such a surcharge is rarely if ever made.

A more rational and equitable basis would comprise consideration of the three items of expense, namely volume, biochemical oxygen demand, and suspended solids. Each of these factors is related to operating practice: the volume definitely increases the expense for pumping, and influences the cost of tanks, channels and aeration equipment; the B.O.D. influences the cost of treatment, possibly in proportion to the increase, and certainly substantially above the mere cost of additional air or filter media required; and the suspended solids increase the cost of sludge conditioning, dewatering and disposal, in proportion to the dry weight.

As an approximation of this basis of evaluation, an empirical example might be set up in the following manner shown in Table I on page 648.

On this basis the industrial waste would be responsible for $8.56 per m.g., whereas on the straight volume basis, the cost would be only $25.50 \times .075$ or $1.91 per m.g. This is obviously inadequate, as the cost of disposing of the sludge ($2.42 per m.g.) would alone exceed this amount.

In most industrial wastes the suspended solids or B.O.D., or both, are usually considerably stronger than in sewage and therefore a charge pro-rated on volume alone will be low. If waste and sewage happen to be of approximately the same strength, even under the minimum costs

TABLE I

Assume:	Industrial Wastes Per Ct. of Total
Flow	7.5
B.O.D.	42.0
Solids	30.3

	Fixed Costs	Operating Costs	Total
Sewage Pumping, per M.G.	$ 1.00	$ 2.50	$ 3.50
Sewage Treatment, per M.G.	8.00	6.00	14.00
Sludge Disposal, per M.G.	3.00	5.00	8.00
Total	$12.00	$13.50	$25.50

	Total Cost per M.G.	Amount Due to Industrial Waste
Sewage Pumping	$ 3.50 × .075	$0.26
Sewage Treatment	14.00 × .42	5.88
Sludge Disposal	8.00 × .303	2.42
	$25.50	$8.56

to the industry, the cost of disposing of the solids should be added. With lower suspended solids in the waste, as for example cooling water from air conditioning, charges based on volume alone might be justifiable.

This method of allocating charges might be simplified by using a scale of surcharges based on type and characteristics of wastes, which would classify them in some half dozen classes, increasing in accordance with the strength or difficulty of treatment. This method is used in the Emscher and Ruhr Districts in Germany.

The Emscher rates include three types of wastes, and the basic charges are doubled or tripled according to the difficulty of treatment. Chemical works and tar distillation plants are in Class III. An elaborate system of surcharges is worked out, based on employees and production.

In the Ruhr District the basic rate is 0.8 M. per capita. A surcharge is added, based on employees or products. For example wood pulp carries a surcharge of 0.25 M. per ton, strawboard 1.2 M., and paper pulp 1.5 M. per ton. Brewery wastes are surcharged 4 M. per employee; dairy wastes, 10 M.; leather wastes, 16 M.; and yeast wastes, 35 M. per employee.

It therefore seems that it is possible to adopt a scale of charges that includes more than volume or a uniform rate per employee. The Ruhr system provides ample protection for industries to appeal to a board of arbitration if the charges are felt to be excessive.

In England the inclusion of industrial wastes with sewage in treatment works has been handled by separate contracts between the industry and the municipality. Until passage of the 1937 Public Health Act (Drainage of Trade Premises), which became effective July 1, 1938, the local authority could refuse to accept industrial wastes into its sewers and treatment works, but now the decision must be left to the Ministry of Health and the municipality is no longer the arbiter. However, it can set the

scale of rates, "regard being had both to the volume and composition of the trade effluents." Most English rates are from 1 to 2 pence per 1,000 Imperial gallons. At Huddersfield, where wool scouring and chemical dye-plant wastes are received in large concentration, the rate is 2 pence.

The most important clause of the 1937 Act is as follows:

Public Health (Drainage of Trade Premises) Act, 1937.

5. A local authority may, and, if required by the Minister, shall, make bye-laws . . . (*l, f*) for requiring the several occupiers of trade premises from which the trade effluent is discharged into the sewer to pay to the local authority such charge for the reception of the trade effluent into the sewer, and for the disposal thereof, as may be specified in the bye-laws, regard being had to the composition and volume of the trade effluent so discharged, and to any additional expense incurred or likely to be incurred by a sewerage authority in connection with the reception or disposal of the trade effluent.

The new act has been in operation in England only since last summer, and the results of its application will be watched with interest both at home and in the United States.

A number of ordinances are in effect in the U. S. designed to provide some basis for an equitable charge for the treatment of industrial wastes. The so-called "Industrial Waste Act" of The Sanitary District of Chicago was enacted by the Illinois State Legislature in 1935. This Act reads as follows:

(*a*) It shall be unlawful, except as herein provided, for any person, firm, association or corporation in possession of or controlling and operating any industrial or manufacturing plant to discharge into the sewers or works of the Sanitary District or into any sewer connected therewith, any waste matter of any nature whatever resulting from or the residue of any industrial or manufacturing operation or process carried on in such plant, where the mixture of such waste matter, sewage and water discharged by such industrial or manufacturing plant into such sewers or works equals in any twelve-month period an aggregate volume of 3,650,000 gallons. Upon the trial of any issue as to whether any person, firm, association or corporation in possession of or controlling and operating any industrial or manufacturing plant shall come within the provisions of this Act or of any ordinance passed pursuant to the power herein conferred, proof that an aggregate volume of gallons daily of the nature herein set forth has been discharged into such sewers or works from such plant for any ten days during a twelve-month period shall be prima facie evidence in all courts and places that there has been discharged an aggregate volume of 3,650,000 gallons of the nature herein set forth, during such twelve-month period.

(*b*) The Sanitary District, in addition to the other powers vested in it, is hereby empowered in the interest of public health and safety, to permit the discharge into the sewers and works of the Sanitary District and into sewers connecting therewith from any industrial or manufacturing plant, a mixture of waste matter, sewage and water as described in paragraph (*a*) hereof, in excess of an aggregate volume of 3,650,000 gallons in any twelve-month period, upon reasonable terms and conditions, including a requirement for the payment of compensation to the Sanitary District for the conveying, pumping, treatment and disposal of such excess.

(*c*) The Sanitary District is hereby empowered to pass all necessary ordinances to carry into effect the powers herein conferred, provided, however, that in fixing the amount of compensation, if any, to be paid to the Sanitary District by applicants for permits to discharge a volume of said mixture of waste matter, sewerage and water in excess of 3,650,000 gallons in any twelve-month period or in arriving at a determination of any other terms and conditions upon which such permits are to be issued, due and proper deductions shall be allowed for the amount of human sewage contained in such excess.

This act has not been applied as yet, because most of the industrial wastes of the District are tributary to the Southwest Treatment Works, now under construction. This plant will go into operation in the summer of the present year.

Industrial Waste Survey

In connection with the Industrial Waste Act, an extensive survey of industrial wastes in the S.D.C. has been in progress for the past four years. Wastes from more than 200 plants have been measured and sampled, usually over a two-week period. Weirs were installed on all outlets, samples were collected each 15 minutes and composited into 12-hour composites in proportion to the flow. At the end of the tests, analyses and flows were combined to give the average losses in pounds per 24 hours, and in most cases, in pounds per unit of product.

This survey is still in progress, so that a complete compilation cannot be made at the present time, but an estimate of the contributions from various types of industry is given in Table II.

Table II.—*The Sanitary District of Chicago*

Summary of Industrial Wastes (Preliminary Estimates)

No. of Plants	Industry	Flow M.G.D.	Susp. Solids Lb. per 24 Hr.	5-day B.O.D. Lb. per 24 Hr.	Population Equivalent
41	Packinghouses	29.37	150,000	152,000	912,000
18	Tanneries	2.93	33,500	22,650	135,900
28	Breweries	3.50	18,800	35,000	210,000
2	Yeast and vinegar	2.43	6,040	26,750	160,500
2	Paper	6.25	22,760	6,530	39,180
2	Tomato canning *	2.92	11,200	21,650	129,900
4	Malt plants	1.93	3,470	14,960	89,760
4	By-products coke	1.73	1,280	18,500	111,000
3	Vegetable oil refining	2.80	3,470	8,060	48,360
3	Tar distillation	1.06	570	3,910	23,460
12	Candy (est.)	4.0	3,600	11,000	66,000
1	Corn products	15.0	4,000	6,000	36,000
—	Laundries (est.)	2.0	3,600	12,000	72,000
—	Dairies (est.)	3.0	9,600	13,000	78,000
	Miscellaneous (est.)	10.0	10,000	20,000	120,000
	Total	88.92	281,890	372,010	2,232,060

* During canning season, Aug.–Oct.

The total flow is approximately 89 m.g.d., containing 140 tons of suspended solids and 186 tons of 5-day B.O.D., equivalent to a population of 2,232,000. This estimate is subject to revision, but it indicates the tremendous overall effect of industrial wastes in Chicago. Possibly laundry and dairy wastes should not be considered as specific industrial wastes, since they are present in all municipal sewages and are normally considered a part of the load that must be handled by all sewage works.

In the English 1937 Act a specific exemption is made for laundry wastes. Elimination of laundry and dairy wastes from the total given in Table II would reduce the flow by 5.0 m.g.d., the suspended solids by 6.6 tons and the population equivalent by 150,000.

The estimate of "miscellaneous" wastes may be subject to some variation more or less, but otherwise the list shows the comparative effect of some twelve types of industrial wastes. A brief discussion of these types may be desirable.

Packinghouse Wastes.—The general characteristics of packinghouse wastes are well known. The 41 plants listed include the stockyards and a glue works, which is a subsidiary of one of the packers. At the time the tests were made the stockyards kill was low, averaging only about 70 per cent of the normal for the preceding 25 years.

These wastes will be treated at the Southwest Works. Special attention is directed toward skimming of grease in the preliminary settling tanks.

Tannery Wastes.—The volume is low and, as would be expected, the suspended solids exceed the B.O.D. Several tanneries have installed settling tanks for removal of the coarser solids, hair, skin, lime, etc., before the wastes are discharged into the sewers.

Breweries.—The population equivalent of the wastes from 28 breweries was surprisingly high, totalling 210,000, or an average of 7,500 each. One of the main sources of wastes from breweries is the liquor squeezed out of the spent grain, before it is dried. Other wastes include spent yeast, wash water, and hop drainage, all high in organic content but low in suspended solids. The B.O.D. load is accordingly about double the suspended solids.

Yeast and Vinegar.—The wastes from large yeast or vinegar works contain a large amount of soluble solids of organic nature, residues of the molasses used as the nutrient material for yeast and as the source of alcohol which is fermented to vinegar. The two plants listed gave a population equivalent of 160,000 based on B.O.D., but the wastes contained only three tons of suspended solids. The total wastes contained all wash water, so that the weighted analysis equals only 298 p.p.m. suspended solids and 1,320 p.p.m. B.O.D. Even with this dilution the B.O.D. is excessive.

It is rather surprising that there are no distilleries in the Sanitary District of Chicago. The wastes from yeast plants, vinegar works, and distilleries are similar in composition.

Paper.—There are two paper mills in Chicago, in which pasteboard or kraft is made from waste paper plus a small percentage of wood pulp. The two plants discharged 22,760 lb. suspended solids, but the B.O.D. was only 6,530 lb. This ratio shows the characteristics of this type of waste—high solids: low B.O.D., and the results may be contrasted with the yeast and vinegar wastes, in which the suspended solids and B.O.D. are in almost inverse ratio.

The paper mill wastes had a weighted average content of 429 p.p.m. suspended solids and 123 p.p.m. B.O.D. Plans are under consideration for reduction of the suspended solids in the wastes.

Tomato Canning.—Wastes from tomato canning are of considerable importance during the months of August and September. One plant has received up to 3,600,000 lb. of tomatoes per 24 hours. The wastes are high in B.O.D., but also contain a large content of suspended solids (11,200 lb. per 24 hours).

Tomato wastes require large dilution with sewage to avoid interference with sewage treatment processes. However, if the sewage treatment works can handle the wastes, it is undoubtedly preferable to any attempts to treat them prior to discharge from the factory. The short season means that the fixed charges on evaporators or any type of biological filtration are excessive.

Malt Plants.—The malting of barley produces a waste that is high in soluble organic solids. Four plants in the S.D.C. have a population equivalent of approximately 90,000.

By-Products Coke.—Ammonia-still wastes and wash water from the final cooler (if not closed circuit) have a high oxygen demand. These wastes have long been a source of nuisance because of their taste-producing power in chlorinated water supplies, but their high oxygen demand is usually overlooked. A large amount of work has been done on these wastes, and several extraction, vaporization or absorption processes are available, at considerable cost, where the wastes must be treated at the coke plant, but biological oxidation in sewage by trickling filters or activated sludge appears to be the most economical and complete process of disposal.

Tar Distillation.—Wastes from tar refining are of minor importance. They are similar to coke-plant wastes, and contain very little suspended matter.

Vegetable Oil Refining.—The refining of vegetable and animal oil (cocoanut, oleo, soya) produces wastes with a rather high B.O.D. Three plants in Chicago have a population equivalent of 48,360.

Candy.—It is surprising to note the large use of water and the high B.O.D. of wastes from candy factories. The source of B.O.D. is largely sugar (dextrose) which is washed out of the kettles and pans in clean-up operations. The estimate of the population equivalent of such wastes in the S.D.C. is 66,000.

Corn Products.—For many years investigations have been made of the wastes from the Corn Products Refining Company. Recovery of solids by evaporation has reduced the population equivalent from more than 400,000 to approximately 36,000. Daily analyses are made of the wastes and the population equivalent computed from the flow and results of analyses. The flow of 15.0 m.g.d. contains about 12.0 m.g.d. of condensing water taken from and returned to the Main Channel of the Sanitary District. The total wastes are therefore quite dilute, with a weighted B.O.D. of only 48 p.p.m.

Miscellaneous Wastes.—A large number of organic wastes are not included in the classified list, such as those from small sausage works, viscose casings, preserves and pickles, sauerkraut, soap, gelatin, and so forth. Surveys have been made in plants of all these types. For the present all of these wastes have been termed miscellaneous.

Other surveys have been made on wastes not of organic nature, but which are of importance with reference to possibly toxic effect on the activated sludge process of sewage treatment used in the Chicago plants. Iron and steel pickling wastes are of first importance in this group. Considerable difficulty has been experienced at the Calumet Treatment Works in the clogging of filtros plates, used for air diffusion, by ferric hydroxide derived from pickling liquors in the sewage. Most of these wastes have been removed from the sewers and discharged temporarily to the Calumet River, while experiments are being made to determine the economics of using the pickle liquor, after chlorination, in place of ferric chloride for sludge conditioning. At the same time the investigations of the American Iron and Steel Institute on the disposal of pickling liquor, under the direction of Professor W. W. Hodge, are being watched carefully in hope that some satisfactory method of disposal may be developed.

Dye works, chemical plants, rubber processing, paint works, and Pullman car works have been investigated. In general, no highly toxic nor acid wastes (with one exception) have been found.

Unit Losses

Several compilations of losses per unit of product on raw material have been made, and more will be computed as time permits. Losses from packinghouses, paper mills and breweries are shown in Table III. The population equivalents based on B.O.D. are interesting:

	Population Equivalent
Per ton of animals killed	157
Per ton of paper board	98
Per ton of beer (8 barrels)	149

The high value for brewery wastes is surprising; one would hardly expect as much B.O.D. loss from a ton of beer as a ton of animals slaughtered.

Treatment of Industrial Wastes

A. Prior to Discharge Into Sewers.—Although it is possible to handle most wastes in sewage treatment works without any pre-treatment at the factory, it is probably to the advantage of the manufacturer to reduce the volume or solids content of the wastes either by modification of processes within the factory or by partial treatment of the discharged wastes. Studies should be made of the possibility of re-using water, or changing wet processes to dry, within the plant. After such modifications have been adopted, screening, skimming or settling of the residual wastes may be advisable, even though unprofitable, in order to avoid deposits in sewers, or to reduce the cost of similar service at the sewage treatment works.

Examples of some of these types of partial treatment or elimination of wastes at the factory are as follows, listed as in Table II:

Removal of paunch manure in packinghouses; skimming and cleaning of catch basins; use of dry rendering process.

TABLE III.—*The Sanitary District of Chicago*

Unit Packinghouse Losses

Plant	Losses per Ton of Kill			Gal. per Ton
	5-day B.O.D.	Suspended Solids		
		Total	Volatile	
1	28.6	25.6	21.9	6,100
2	24.2	22.0	18.4	4,850
3	25.4	28.0	20.9	5,440
Avg.	26.1	25.2	20.4	5,460

Unit Paper Losses

Plant	Losses per Ton of Products			Gal. per Ton
	5-day B.O.D.	Suspended Solids		
		Total	Volatile	
1	16.8	42.9	30.1	18,300
2	15.9	64.7	49.8	14,700
Avg.	16.3	53.8	40.0	16,500

Unit Brewery Losses

Avg. of Plants	Losses per 31-gal. Barrel			Gal. per Bbl.
	5-day B.O.D.	Suspended Solids		
		Total	Volatile	
28	3.1	1.68	1.28	350

Screening and settling of tannery wastes to prevent matted deposits in sewers; use of depilatories other than sulfides in tanneries, to reduce B.O.D. of wastes.

Improved presses or filters in breweries for recovery of grain; recovery and use of brewers' yeast; separation and re-use of water in refrigeration plant.

Careful control of centrifugal separators in yeast factories; utilization of still residue from weak spirits distillation in vinegar works.

Use of the newer processes for recovery of paper fiber, such as the A D K A or Karlstrom flotation processes, with accompanying reduction in use of water.

Screening of canning (tomato) wastes; recovery of pulp for fodder.

Studies of methods for reducing malt solids in wash water.

Use of extraction or vaporization process for ammonia-still liquors, prior to discharge to sewer; installation of closed circuit for final cooler.

Improvement of skimming devices in vegetable oil refining or hydrogenation plants; use of less water in condensers.

Effective separation of tar and water; study of improved recovery of naphthalene.

Reduction of loss of sugar from candy kettles.

Use of surface condensers for steep-water evaporators in starch works; vaporization of volatile solids.

Equalization of flow of acid wastes from chemical industries, with neutralization by alkalies or by the natural alkalinity of the sewage.

Many of these improvements in waste recovery have been adopted or are under consideration by various industries included in the Sanitary District survey. Practically all industrial wastes will be discharged into sewers tributary to treatment works when the program of sewage treatment is completed.

B. Prior to Direct Discharge Into Streams.—When industrial wastes are discharged directly into streams, without presence of sewage except from the employees, more complete processes of treatment are usually essential at the factory than when the wastes are discharged to a sewage treatment plant. In the former case, it is usually necessary to study the treatment of wastes in a large-scale testing station.

The Sanitary District has operated large-scale testing stations over a number of years on packinghouse wastes, tannery wastes and corn products wastes. In more recent years the policy of treatment of such wastes with sewage has been adopted, consequently no working plants have been built along the lines indicated by the testing-station results. However, the results of the packinghouse and corn products tests have been published, and reports have been made covering the tannery testing station results.

Many testing stations have been operated to study the treatment of industrial wastes, particularly in Wisconsin, Michigan, Ohio, Pennsylvania, Iowa, Texas and elsewhere. A recent Bulletin (No. 82) from the Michigan Engineering Experiment Station, by E. F. Eldridge, outlines methods of treatment or improvement of beet sugar, milk products, canning, meat packing, tannery, textile, laundry, pulp and paper, and metal treating wastes. The costly phenol-oxidizing plant of the Dow Chemical Company at Midland was designed on the basis of testing-station data.

It is impossible to review the many experimental investigations of the treatment of industrial wastes here, but this has been done comprehensively by L. F. Warrick and R. S. Weston in "Modern Sewage Disposal," the Anniversary Book of the Federation of Sewage Works Associations, edited by Langdon Pearse.

Industry's Opportunity

In this paper, the responsibility of industry for alleviation of wastes has been reiterated, but acknowledgment should also be made of the many costly investigations that have been carried on by various manufacturers and trade associations on the treatment of their wastes. The Howard process developed by the Marathon Paper Mills, the work of Standard Brands at Pekin, Ill., the remarkable recoveries effected by the Corn Products Refining Company at Argo, the reduction of a tremendous pollution load by distilleries at Peoria, the extraction of phenol from coke-plant wastes, the oxidation of phenol at the Dow Company, the

studies on dairy waste treatment by Dr. Trebler for the National Dairy Association, the investigations of the Textile Foundation, the Halvorson Process installed at the Hormel Packinghouse, the Domogolla Process at the Madison packinghouse of Oscar Mayer, the U. S. Industrial Alcohol recovery plant at Baltimore—these and many other achievements should be credited to manufacturers who have accepted the responsibility of providing adequate disposal of their wastes. The increasing list of these investigations and plant installations in recent years indicates that industrial executives are becoming more receptive to the idea of providing for waste disposal in the annual budget.

A logical program for all industries is that one proposed by the Michigan Stream Control Commission for the paper mill manufacturers at Kalamazoo, in which the following steps are recommended:

Employment by industries within this zone of such technical assistance as may be necessary, acting individually or jointly, to reduce waste losses to practical minima for their respective mills and operating requirements.

Undertaking and completion of these internal mill changes to accomplish the above objectives.

A comprehensive consulting engineering survey of the polluting strength of municipal sewage and residual industrial effluents for the purpose of arriving at the most satisfactory and economical means of meeting the established stream standard. If acceptable alternate methods of procedure exist, they should be noted.

Here a logical and practical program is presented for the alleviation of excessive pollution. Similar procedure can be recommended for all industries faced with pollution problems.

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THE TREATMENT OF TEXTILE WASTES *

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A discussion of the methods of treating textile wastes seems almost redundant at this time. One must have in mind the publication by The Textile Foundation of a survey of the present knowledge of the subject by Geyer and Perry, with the cooperation of the University of North Carolina, in counsel with Dr. H. G. Baity and a group of distinguished consultants. Also, something has been written on the subject of textile wastes [1] in "Modern Sewage Disposal" the anniversary volume of the Sewage Works Federation, and, on May 3, Prof. E. W. Moore of the Harvard Engineering School presented a paper before the Boston Society of Civil Engineers on "Recent Developments in Trade Wastes Treatment" which had to do with some of the methods used in treating textile wastes. Other articles, one by the writer on wool-scouring waste,[2] have appeared in the recent literature. An exhaustive list of references is contained in the report of The Textile Foundation.

While much has been written regarding the treatment of textile wastes, the industrial depression particularly in New England, where the textile industry has suffered severely, has held back the construction of treatment works even where streams are befouled to a condition of nuisance.

The Processes Which Produce the Wastes

The processes which produce textile wastes may be described for the engineering reader as follows:

Bleaching.—The bleaching of cotton cloth—gray goods, so-called—is typical, although cotton, linen and other fibers as well as their respective yarns and cloths, are also bleached.

The raw cotton cloth ("gray goods") which comes to the bleachery, and which is usually singed, requires treatment with a compound containing diastase, like malt extract, to convert the sizing or the starchy vegetable matter on the goods into sugar which may be washed out with water. Further preparation is given in kiers.

Kiers are large, vertical, pressure boilers or tanks into which the cloth is carefully packed in rope form and then boiled for several hours in a solution of soda ash or caustic soda, or both, at temperatures as high as 125° C. (257° F.), to dissolve the extraneous ligneous, resinous and other organic matter and set free the true vegetable fiber which is largely cellulose. The waste which is drawn from the cloth is known as kier liquor.

The cloth from the kiers is then passed through a washer to remove the excess of kier liquor, the waste from which is known as kier wash water. The cloth after one or two washings, is bleached by being passed through

* Presented at the Spring Meeting of the New England Sewage Works Association, West Springfield, Mass., May 15, 1939.

a solution of chlorinated lime or soda, called "chemic," and allowed to remain carefully piled in a storage bin long enough to bleach the goods to the desired degree, by oxidation with hypochlorous acid.

The bleached goods are taken from the bin and washed in dilute acid to remove any lime or alkali in the fabric. The soured cloth is then washed, usually twice, and dried. It is then ready for dyeing or printing.

Sometimes cloth is bleached with the aid of sodium peroxide which is added in the kiers. It is then soured, washed, perhaps treated with chlorine and an anti-chlor, and washed again. Sometimes the peroxide process is applied to goods which have been first mercerized and washed.

A large part of the wash water from bleaching may be discharged into streams with impunity, but the diastase waste, and especially the kier liquor and the kier wash water present a difficult problem of treatment and disposal.

The bleaching of yarn is a similar process.

Mercerizing.—The mercerizing process, named after its discoverer, the English chemist, Mercer (1884), as applied to cotton cloth, consists in treating the goods with a concentrated cold solution of caustic soda (10 to 30 per cent) for two or three minutes, usually while the fabric is stretched and kept so until after washing, in order to avoid shrinkage. Mercerizing changes the flat cotton fibers into ones more nearly cylindrical. They present a lustrous appearance and are stronger and denser than in their original state.

The alkali in the mercerizing waste should be recovered by evaporation and re-used, perhaps leaving some dilute wash water for discharge into a stream or treatment works. Dialysis is sometimes used to purify the alkaline waste before evaporation.

Textile Coloring.—Textile coloring includes both stock and fabric dyeing and printing.

Processes of dyeing have changed materially in the past eighty years. Formerly, natural dye-stuffs, like indigo, logwood, madder, fustic and cutch, and such mineral dye-stuffs as Prussian blue and the iron and chromium colors, were used exclusively. Some of these, like indigo and logwood, are still used, but with the discovery of mauve, the first of the coal-tar dyes, by Perkin, in 1856, the use of artificial organic dye-stuffs began. Today, the dyer has several hundred of these dyes at his disposal, and can select those to meet nearly every requirement of color, hue and fastness. Dyeing will be discussed briefly, from the dye-house waste standpoint, only.

Indigo, either natural or artificial, is still extensively used—the natural dye for wool and cotton, the artificial dye for cotton only. The so-called "Indigo White" produced by reduction, is absorbed by the fibers, and after aeration, develops a typical blue color. The zinc used as a reducing agent in producing the dye, is often recovered. The process, used for other dyes, also, is called vat dyeing.

Logwood is used in the form of logwood liquor, prepared from logwood chips or logwood extract, a commercial product. Only a part of the dye liquor—the haematein—does the dyeing, and a metallic mordant,

like iron chromium or copper, must be used to fix the dye. While logwood has been largely replaced by artificial dye-stuffs, it is still used because it is economical, one of its uses being for the speck dyeing of worsted cloth. The logwood dye wastes, consisting largely of wash water, are highly colored and high in organic matter.

There are a dozen different kinds of artificial organic dye-stuffs, acid, basic, direct, mordant, reducible, and others. Some of these have an affinity for one fiber only, a few have affinities for all.

Some dye-stuffs, like acid dyes for wool, are nearly completely absorbed. However, the dye bath by which they are applied to the fibers may contain an acid, like sulfuric acid, also sodium sulfate or sodium bisulfate.

Direct dyes, among which are classed the azo dyes, are so named because they require no mordants or accessary chemicals to fix them on the vegetable fibers. The dye bath may contain from 0.1 to 10 per cent of dye and from 3 to 40 per cent of sodium chloride or sulfate.

Basic dyes are those which will dye animal fibers directly and vegetable fibers with the aid of a mordant.

A typical process is one in which the goods are first boiled in a bath containing a soluble oil or other accessory. They are then thoroughly saturated with tannic acid in a second bath, followed by treatment with a salt of antimony (tartar emetic), in a third bath. Usually a rinsing follows. Then comes the dye bath proper, containing the dye and an organic acid, like acetic acid; after this, treatment in an oil finishing bath completes the process. The acid is volatilized by heat.

When basic dyes are applied to wool or silk, mordants are not always used. Chromium compounds are mostly used for mordanting wool, while for silk, various metals, including tin, are used. Tin, in the form of stannic chloride, is also largely used for the weighting of silk. It is readily absorbed and is fixed on the fiber by washing in water containing lime or sodium phosphate. Sometimes, sodium silicate is used with the tin.

Tin is recovered from the waste waters by reduction with zinc and smelting, or by neutralizing the acid waste with lime, with the production of tin oxide which subsides from the treated waste and is later recovered and converted to stannic chloride.

Sulfur Dyeing.—Sulfur or sulfite colors are used for producing fast blacks, browns, blues and greens, and combined shades, on cotton. They are so named because they contain sulfur, and because sodium sulfide must be used for their application.

In general, they are applied in a bath containing 1 to 20 per cent of the dye plus sodium sulfide in an amount from one to four times the weight of the dye-stuff. The dye bath also contains from 5 to 7 per cent of sodium carbonate and sodium sulfate, or common salt, amounting to 20 to 50 per cent of the weight of the material dyed.

Flax.—Although the manufacture of linen and other fabrics from flax is an important industry, most of the preparation of the fiber by retting is accomplished abroad, generally where the flax is grown.

The retting process consists in steeping bundles of flax plants in water when fermentation of the pectose, which binds the bast fibers together, takes place. The process is a septic one and produces an offensive waste high in organic matter and B. O. D.

According to Howard, Gleason and Merrifield [3] 5300 gal. of retting waste are discharged per ton of flax straw. This waste has an average 20-day B. O. D. of 4900 p.p.m. and contains 4200 p.p.m. of total solids, most of which is in solution. The waste is acid and has a pH value of less than 5.0.

Other Vegetable Fibers.—Jute, hemp, sisal and other fibers are used for making coarser fabrics, like bagging, covers, mats and cordage. They are rarely completely bleached but are usually prepared for use by alkaline boiling in kiers, or in rotary boilers. The rotary boiler liquor is even more polluting than the kier liquors from bleacheries and usually requires similar treatment. Some of the kier liquors may contain more than 4 per cent of total solids. Some of these fibers go through a wet spinning process, the waste from which is high in organic matter including waste fiber and high in matters soluble in ether.

Jute and some other fibers are readily dyed and the waste from dyeing this fiber is frequently of importance from a stream pollution standpoint.

Printing.—Printing of cotton and other fabrics is accomplished by continuous pressing in machines which include one or more engraved cylinders which receive the pasty color from a feed roll (furnisher) which dips into a trough-like vessel containing the dye in paste form. A blade (doctor) scrapes away the excess of dye from the roll before it is applied to the cloth by pressing the latter between a rubber covered roll or cylinder and the printing cylinder. Chemicals in paste form are also applied in the same way to discharge part of the color previously printed.

In order to fix the color and prevent its spreading, the fiber is steamed. This fixes the color without immersion, and volatilizes substances like acetic acid contained in the color.

For printing cotton textiles, basic or mordant coloring matters are commonly used, enough gum, dextrin, starch or other thickening being added to form the pasty mass used for dyeing.

Very little of the expensive dye-stuff is wasted, and the waste from the color shops and the sinks in which the cleaning of the rolls and machines is accomplished, while highly colored, is small in volume and of little importance from a stream pollution standpoint, excepting for its effect upon the color of the stream, especially when discharged batchwise.

The Connecticut State Water Commission has recommended that waste color pastes be separated and incinerated.

Finishing.—All sorts of compounds, chiefly starches, waxes, gums, and sometimes synthetic products are used to load yarn and fabrics. Silk is loaded with tin, cambric with starch and/or gum, while lustrous surfaces are imparted to low-grade fabrics to give them the appearance of better ones.

Usually these finishes, or fillers, are applied on a special machine, a "back-filler" for example, after which the yarn or fabric is dried and calendered between heated rolls.

Wastes from these processes occur for the most part at times when the backfilling or other machines are dumped for cleaning or changing the processes.

Wool Scouring.—Wool scouring waste results from the washing of wool in water with added soap, sodium carbonate and other detergents. Usually the wool is dusted before being scoured, and in this connection the freezing of the wool before dusting has been proposed and now is in use at two important New England mills.[4]

In a few mills the grease in the wool is removed by a solvent, like naphtha, after which the wool is scoured, using much less soap and alkali than when scoured in its raw state.

Wool as removed from the sheep's body contains much besides wool fiber, depending upon its kind and character. It may lose from 20 to 75 per cent of its weight in the scouring process. This loss includes the bodily excretions of the sheep, known as "yolk" (French, *suint*), which are partly soluble and partly insoluble in water. Wool also includes sheep manure, plant parts and geological samples of the lands inhabited by the producing sheep.

Other animal hairs, like mohair, alpaca and camel's hair, are also scoured. While often dirty, their grease contents are low. Quantitatively, mohair is the most important of these.

The soluble matters in the wool include potash soaps which are combinations of oleic and other fatty acids. When the wool is washed, these soaps, and the added detergents, cause emulsification of the wool grease. True wool grease does not form a soluble soap with alkali. Chemically, it is a wax rather than a fat. It consists of various esters of cholesterol and iso-cholesterol; cetyl; and carnaübyl and ceryl alcohol with oleic, lanopalmitic and other organic acids; also other compounds, like free cholesterol, in small proportions. In its refined state, wool grease is called lanolin (*Adeps lanae*, U. S. P.), valuable for ointments, salves and emulsions.

The process of wool scouring has been described in detail elsewhere.[2] In plants of considerable size it is carried on in trains of long bowls through which the wool is gently dragged by means of mechanically operated rakes or forks. The bowls are usually arranged in trains of four or five, with the train varying in width from 24 to 48 inches and in length from 12 to 30 feet. In each train the longer bowls are used for scouring with soap and other detergents, and the shortest bowl for the final rinsing.

There is a perforated screen in each bowl with settling compartment beneath, and above the screen the depth of liquor through which the wool is dragged is usually less than 12 inches. Pyramidal bottoms and drains are provided for dumping part or all of the contents of the bowls. Some bowls have auxiliary settling tanks alongside, with pumps for circulating the scouring liquor through them, thus keeping down the accumulation of grit and dirt.

The sorted wool, previously dusted, is introduced at the near end of each bowl by a traveling apron, and is dragged slowly through the bowl by mechanical forks or rakes, and then passed through squeeze rolls at

the far end, which rolls deliver it to the feeder of the next bowl, or, in the case of the last bowl, to the conveyor leading to the wool drier.

Most wools are easily scoured in an alkaline soap solution, but detergents, like tri-sodium phosphate, sodium metaphosphate, or sodium silicate, and those containing cresols and other deodorants, are used in special cases. Sometimes, and usually in the counter-current process, no soap or alkali is added in the first bowl.

Temperatures are usually kept below 140° F. to avoid injury to the wool fiber. Common operating temperatures are 130° F. in the first, 125° F. in the second, 120° F. in the third, and normal water temperatures in the rinsing bowl. Recording thermometers are in use in some mills, also automatic temperature controllers.

Counter-Current Scouring.—In most wool-scouring plants the bowls are dumped singly or batchwise, although frequently the water from the last or last two bowls in the train is discharged continuously, even if the bowls are dumped periodically in addition. These bowls are used for rinsing the wool.

Batch dumping results in large consumption of water per pound of wool, very few mills using less than 1 gallon, and some more than 5 gallons, per pound of wool.

An accurate study made by the Metropolitan District Water Supply Commission in 1935, in cooperation with the engineers, the Barre Wool Combing Company, a typical commission combing plant, showed an average of 1.99 gallons and a minimum of 1.6 gallons of water used per pound of wool.

A similar study made in 1936 at a typical high-grade worsted mill by the writer's firm showed an average use of 1.3 gallons in the first three bowls and of 2.0 gallons in the fourth bowl, a total of 3.3 gallons per pound of wool. At this plant the fourth bowl discharges continuously between customary six-hourly dumpings of all the bowls.

A large use of soap and alkali naturally follows a large consumption of water, for a sufficient concentration must be maintained regardless of the volume of water used. It is also a fact that a larger percentage of grease is recoverable from concentrated than from dilute waste, in either the centrifugal process or the acid-cracking process of recovery.

The above facts have led to the employment of the counter-current method, which is in general use in chemical industry. When this is used, only the first bowl liquors are discharged, and these continuously at a slow rate, the loss being made up by pumping from the other bowls in the train in turn.

The counter-current method is not only advantageous because the concentration of soap and alkali and other detergents can be maintained as desired and at the points desired, but also for grease recovery, because the heaviest of the interfering dirt is discharged to waste periodically, while the wool grease reaches a higher concentration when discharged from the first bowl only.

While the continuous process has been used in connection with the centrifugal process of grease recovery, it is equally advantageous in

connection with the acid or any other method of treating the waste. It affects waste treatment because it reduces the volume of waste to be treated, and increases the yield of grease recovered.

The difference between the batch and continuous methods is illustrated by the accompanying flow sheet (Fig. 1).

Silk.—Before silk can be bleached or dyed it must be de-gummed or stripped. The process is analogous to the scouring of wool. Raw silk contains from 60 to 70 per cent of fibroin (the fundamental constituent of pure silk), and from 25 to 35 per cent of sericin, which is the gum surrounding the individual threads and holding them together.

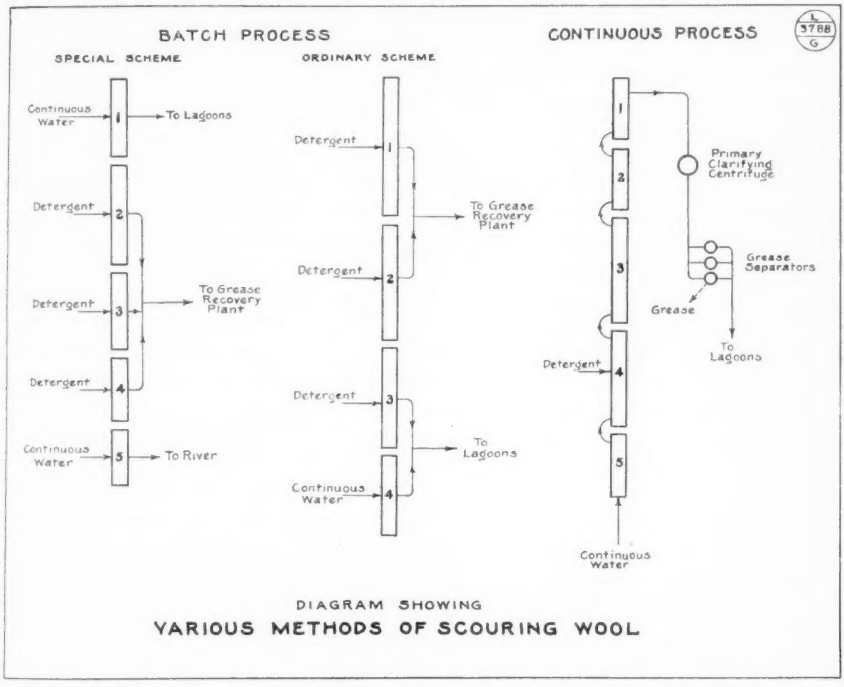

FIG. 1.—Diagram showing various methods of scouring wool.

While wool must be scoured at temperatures of 140° F. or less, silk may be de-gummed in a succession of two or three bowls of boiling neutral soap solution containing from a fifth to a quarter as much soap as raw silk by weight. The period of boiling in each bath is about thirty minutes and is followed by rinsing.

What is known as "tram silk" is boiled out with soap at 95° F. (35° C.), after which it may be decolorized by immersion in dilute nitric acid at a low temperature (20 to 25° C.) for fifteen minutes, followed by thorough rinsing. Tram silk may be bleached with sulfur, like ordinary de-gummed silk which is called organsine. Bleaching with sulfur or hydrogen peroxide is necessary before silk can be dyed to a pale or delicate color.

The dyeing of silk is similar in method to that of wool. Sometimes, dressings like starch, oil emulsions, soap emulsions, etc., are used to facilitate spinning and weaving. These interfere with the dyeing of fabrics. It is vital, therefore, to clean the silk thoroughly before dyeing.

The characteristic rustle of silk is imparted by treatment with weak acid (1 to 2 per cent) followed by drying without rinsing. This treatment may shorten the life of the silk.

Silk dyeing is usually accomplished in soap baths, using from one-third to one-quarter of the soap solution remaining after de-gumming the raw silk. This is acidified with sulfuric acid. The dye is then added and the silk immersed in the bath. The dyed silk is then rinsed.

Silk is usually impregnated or weighted with various substances, tin and tannin for example, to increase its weight, usually by one-third to one-half of the original weight, and in the case of certain kinds of black silk by 300 per cent or even more. The higher weightings are obtained by repeated immersions in the various baths. For example, silk first treated with stannic chloride is then treated with sodium phosphotannate, and silk first coated with iron oxide is successively treated with tin, tannin, and logwood extract. It is then washed and dried. The tin may be recovered from the waste, as stated elsewhere.

Artificial Fibers.—Rayon, celanese, viscose, or other so-called "artificial silks," while so named, are really lustrous cellulose. In one process, the cellulose, first treated with alkali and dissolved in alkaline carbon disulfide, is jetted into a hot acid bisulfate solution to coagulate the dissolved cellulose. The threads so formed are thoroughly washed, dried, steamed and treated in hot sodium sulfide solution to remove the last traces of sulfur. They are then washed again, bleached like cotton, and dyed like mercerized cotton.

While much of the alkali used to prepare the crude cellulose for treatment is recovered from the waste by dialysis and evaporation, large amounts of water are used for rinsing, and the B.O.D. of the combined wastes is high.[5]

Treatment of the Wastes

The first consideration in the treatment of textile wastes is the capacity for self-purification of the body of water into which the treated wastes will be discharged. This consideration is emphasized by the regulations of the stream pollution authorities. These vary from absence of restriction to prohibition of the discharge of anything which "may become inimical or injurious to the public health or to animal or aquatic life, or prevent the use of waters for domestic, industrial or recreational purposes."

Ordinarily, this means the study of stream discharge, upstream and downstream conditions, sanitary hazards and other factors of use. In this connection, the use of the river for water supply is paramount and the demands of the recreationists are vital and increasing. Then follows the determination of the volume and character of the waste. While much

help may be gotten from the literature and from experience, each case is *sui generis*, peculiar and variable.

The minimum for a beginning is to ask the mill management to arrange a typical day of maximal operation and then sample and analyze everything in sight. In this examination, variation in strength should be determined by frequent sampling and determinations, while integrated samples representing parts of the whole day may be taken for general analysis. It is wise to make more than one examination of this kind. Usually, distinction between the working day and the remainder of the 24 hours must be made.

The next step is to determine what wastes, rinsing waters and the like, may be discharged without treatment. For example, it was found at one plant that the washings from a cloth-washer for the first seven minutes should be treated, while those for the remainder of the half-hour period might be discharged into the stream untreated, with impunity. In some cases, 60 per cent of the waste may be discharged without treatment.

After the purifying capacity of the stream is known and a decision is made regarding the separation of wastes, then follows the determination of the degree of purification required for remaining wastes.

In estimating this condition, the engineer should be careful not to base his design upon too few data. As many observations as is practicable should be made and ample allowance should be made for any possible change in the processes; for example, a textile mill which was started in Rhode Island to card, spin and weave and do a little dyeing considered its waste treatment problem. A study was made and works were built. Then followed the introduction of bleaching and more dyeing, adding kier liquor to the waste and greatly changing its character. On the other hand, a finishing plant in the north ceased to dye wool and the manufacture of several special products, which reduced the strength and volume of the waste to be treated.

After determining the character and variations in composition of waste, the degree of purification required, which wastes may be discharged untreated, what concentrations and what re-uses may be made, and having planned some method to equalize the daily discharge by storage, the choice of the type of treatment is next in order.

If the wastes contain kier liquor, wool- or silk-scouring waste, cloth-washing waste, or some of the spent-dye liquors, like sulfur black, some special treatment is usually indicated, before they are added to the remaining wastes.

Although the recovery of by-products from kier liquor has not been studied to its limit, some progress has been made toward improving the treatment of such liquors and lessening the inhibiting effect on the treatment of other wastes. Carbonization promises much (14).

The writer's firm has found that if the liquor is stored in lagoons for six weeks or less it absorbs carbon dioxide from the air and loses some of its inhibiting action when mixed with other wastes. While the unstored liquor would sterilize a large volume of other waste when added thereto,

the stored waste may be treated on a trickling filter at a rate of 1 m.g.a.d. Kier liquor may also be treated with the carbon dioxide in the gases drawn from the mill stack. In such an installation made under the direction of the writer's firm, experiments by the Massachusetts Department of Public Health showed that the uncarbonated wastes required 150 volumes of natural water for dilution; the carbonated, 50 volumes. Filtration of the concentrated liquor at the rate of 1 m.g.a.d. reduced the requirement to 35 volumes.[6]

Reduction in Volume.—Many plants, especially those on large rivers or below large mill ponds, are prodigal in the use of water. When this high use is for rinsing and coupled with discharge without treatment, it is of little moment, but when it increases the volume of wastes to be treated, it is a serious matter.

The application of the counter-current method is often of great benefit. In wool scouring, it may reduce the amount of waste to 25 per cent of the ordinary volume. It is applicable to dyeing, soap washing, and other processes. In some cases, wastes may be treated and re-used.

Volumes of wastes may also be reduced by recovery, as of caustic soda from the mercerizing process, tin and tin salts from silk-weighting waste, fatty acids from cloth-washing waste, and wool grease from wool-scouring waste.

Winkelmann [7] has suggested the use of electrolysis for removing fats from soapy wastes by coagulation followed by centrifugalization.

Hall [8] has recovered sodium ferrocyanide from dye wastes, and the possibilities for the recovery of alkali and valuable by-products from kier liquor, the recovery of sericin, a valuable dye assistant, from silk-washing waste, and various accessory chemicals from dye liquors invite research.

Distribution.—Some wastes, like kier liquor and some dye house wastes, are usually discharged batchwise, but their effect is far less noticeable if batch discharge be avoided and the flow be distributed throughout the day.

At the Cranston Print Works in Rhode Island, the kier liquor is dumped into a tank and then pumped into the waste drain by means of a Dorrco pump, the speed of which is varied to distribute the discharge of liquid throughout the 24 hours of the day. The variations in the alkalinity of the discharged wastes are shown in Fig. 2.

Equalization of discharge may also be approached by storage of the combined wastes in tanks with or without mixing.

Storage.—Even with the modern electrolytic method of control, proper dosing with chemicals of textile wastes as discharged is impracticable, while variations in the chemical composition, due to the batch discharge of kier liquor, sulfur dye wastes, chrome liquor, soapy and starchy wastes, and the alternation of acid and alkali, interfere with biological treatment.

Therefore, storage is required to equalize the discharge. There are exceptions to this requirement. Sometimes storage may be combined with subsidence or chemical treatment. Occasionally co-precipitation occurs.

Wool-scouring wastes require the partial recovery of grease by the

acid cracking, or the centrifugal process.[2] Both processes may be affected by the use of solid alcohols, sodium metaphosphate, and other dispersive detergents which may require secondary treatment in the case of the acid-cracking process. In the centrifugal process, the degree of separation of grease is reduced.

In the Duhamel process (and in similar patented processes) the centrifugal effluent is evaporated after clarification with chemicals, and

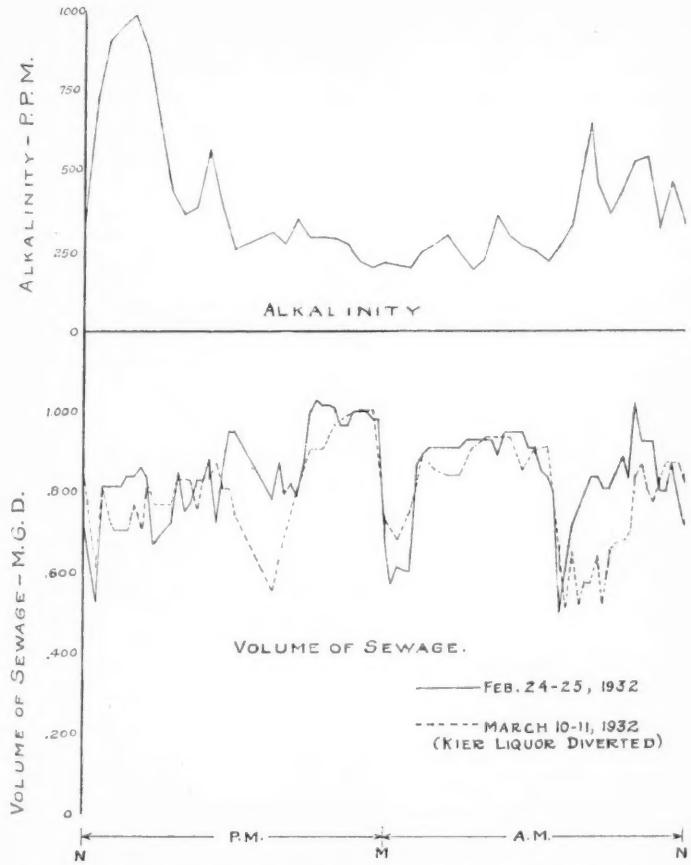

FIG. 2.—Printing and finishing wastes. Hourly variation in volume and alkalinity.

the soluble solids recovered for fertilizer. However, processes of this kind should be examined carefully before adoption. Recently, the writer's firm examined a similar process employing evaporation and found it to be uneconomical under present market conditions.

Sometimes the effluent from the treatment of wool-scouring or cloth-washing wastes may be successfully treated if diluted with other wastes or sewage. Cloth-washing wastes present a less serious problem than

wool-scouring wastes, but, like them, they are affected by the use of dispersive detergents which interfere with chemical treatment.

In brief, one has to treat, among others, the ligneous and resinous wastes from vegetable fibers, the greasy wastes from wool, silk and cloth washing, the dye house and printing wastes, including some of the waters used for rinsing.

Characteristics of Wastes.—As Hedgepeth and Griffin state so well,[9] "The most consistent thing about textile wastes is the fact that they will consistently change." Therefore, the publishing of results of analyses is of little service to the designer, and this because, to state it again, each case presents a new problem requiring preliminary study and for best results a try-out of the process on a semi-plant scale. However, some of the results given in Table I may show how textile wastes compare with those for domestic sewage and how widely variant are the wastes.

TABLE I.—*Results of Analyses*

Waste	Per Cent Settleable Solids	Parts per Million							pH Value
		Oxygen Consumed	Total Solids	Suspended Solids	Loss on Ignition	Alkalinity	Ether Soluble (Fats)	B.O.D.	
Separated bleachery waste†	0.53	319	1,610	218	218	373	—	313*	10+
Kier liquor (caustic)	—	1,350	8,140	550	5,480	3,040	—	—	—
Kier liquor (peroxide)	—	3,792	16,270	2,329	2,395	4,580	—	47.6*	11.2+
Kier liquor (soap kier)	—	958	6,588	716	2,122	3,820	—	17.7*	11.2+
Acid wash water	—	60	80	15	51	12	—	15.4	6.4
Dye back soap waste	—	548	1,853	412	926	650	—	554	9.8
"Calgon" washer waste	—	216	1,390	92	258	165	—	165	7.2
Soap washer waste	—	848	1,747	513	1,392	310	—	651	8.9
Print washer waste	—	292	3,720	292	565	155‡	—	100	3.7
Avg. kier liquor (jute)	—		20,184	72	11,490	—	—		
Wet spinning waste (jute)	—		5,588	—	4,782	160	784	—	
Dye waste (colors)	—		6,390	—	1,920	1,100	—	—	
Wool-scouring waste									
1st bowl, Yangtze wool	27.0		119,000	80,000	—	12,300	10,450	—	
Mill F	—	26,100	114,112	83,912	72,448	—	44,175	—	
Mill A	—	7,900	25,475	14,950	17,415	3,125	11,220	4,464	
Mill B	0.21	13,700	42,312	16,760	27,870	12,300	9,835	10,360	
Mill H	—	230	1,960	700	1,530	550	520	702	
Carbonizing waste									
1st bowl	—	4,110	45,770	21,350	29,670	8,100	10,100	—	
Worsted mill									
Composite waste	—	275	1,640	370	1,010	212	210	216	
Dye liquor (logwood)	—	3,400	10,140	1,390	4,850	3,200	—	459	
Speck dye house waste (Integrated)	—	425	1,430	210	850	330	—	85.6	
Soap scour wash water	—	30	380	80	290	44	—	16.2	
Soaper waste	—	2,100	9,340	4,160	5,880	3,500	—	702	
Ammonia bath	—	50	560	150	410	1,900	—	37.8	
Spent dye liquor (Integrated)	—	700	5,990	570	3,820	1,250	—	926	
Dye house wash water	—	230	2,090	290	1,290	48	—	312	
Laundry waste	—	221	760	351	549	140	346	262	10
For Comparison									
Sewage									
Bristol, R. I. (Separate system)	0.21	155	915	126	293	189	16.5	195	—
Cleveland, O. (Combined)	—	66	678	184	—	188	—	163	—
Fitchburg, Mass. (Separate)	—	136	473	290	236	—	—	154	—

* Results are unreasonably low due to disinfecting action of waste.
† About 40 per cent of total waste.
‡ Acidity.

Comparison.—Unless some of the wastes, like kier liquor, are neutralized before the determination of the B.O.D., the results may be mis-

leading. This is due to the disinfecting or inhibiting action of the constituents of the wastes. Low results, because of the effect of this factor, bear no relation to the oxygen demand of the waste when diluted in the stream.

Some recent results by approved methods, taken from the Geyer and Perry report and obtained in the laboratory of the writer's firm, show the biochemical oxygen demands of various wastes. These may be compared with other wastes and with sewage, as shown in the following table.

TABLE II.—*Biochemical Oxygen Demands of Wastes and Sewage*

Waste	5 days at 20° C. P.p.m.
Cotton thread	550
Finishing—cotton piece goods	605
Elastic webbing and brake linings	422
Silk	460
Cotton finishing	540
Cotton and rayon finishing	390
Fish lines—finishing	180
Cotton cloth finishing	478
Rayon—bleaching, dyeing and finishing	1920
Woolen—scouring, dyeing and finishing	936
Felt	156
Laundry	154
Wool scouring	4000 to 10,000
Soaper waste	702
Average sewage	150 to 300

According to Metcalf and Eddy,[10] sewage of cities with separate sewers receiving industrial wastes will have an average B.O.D. of 273 p.p.m., while that of cities receiving none will have an average of 162 p.p.m.

Special Methods.—In view of the recent publications of final methods of treatment, and because of the desirability of studying each plant by itself, it seems redundant to re-describe the mechanical, biological and chemical methods from which selection must be made to fit a particular case. However, the method of approach to the problem may be discussed.

In any case, it is well, as Hedgepeth and Griffin[9] express so well, "to beware of the specialty product—for its miracle helpeth you not."

Equalization of Discharge and Subsidence.—Equalization of discharge and subsidence, the simplest methods of treatment, are usually indicated. Here one may have to decide between mechanically and hand-cleaned tanks. Here again, the 5-day week and the available time for cleaning ordinary tanks over the week-end, should be kept in mind.

Some of the wastes, like those from some finishing plants, have less than 1 per cent of settleable solids and less than 30 per cent of this may be removed without chemical treatment. On the other hand, some of the wool scouring wastes from a carpet mill scouring Chinese wool may contain 27 per cent (by volume) of settleable solids.

Treatment of Wool-Scouring Wastes.—Treatment of wool-scouring

wastes has been described in considerable detail by the writer in another paper.[2]

The two methods which are most often used are known as the acid-cracking and the centrifugal process, respectively.

Acid Process.—The acid, or acid-cracking, process consists in adding sulfuric acid to the cooled wastes, with storing and sometimes with the addition of clay, silt or other substances to load or demulsify this dispersed grease. Properly treated waste usually has an acidity of from 0.1 to 0.2 per cent.

After treatment and subsidence, carried out in tanks, the sludge containing from 70 to 90 per cent of the grease in the waste is passed through a filter press and the grease recovered from the cake by steaming. The acid supernatant liquor is decanted and given further treatment if necessary.

Centrifugal Process.—For about twenty-five years, centrifugal machines, similar to those used to separate cream from milk or for purifying oil in power plants, have been used to separate wool grease from wool-scouring waste, first freed from the grosser settleable solids by subsidence in tanks or by primary centrifugalization.

In this process, the waste is treated to remove settleable solids, then heated to 160° F. (71° C.) and passed through centrifugals. These remove from 40 to 60 per cent of the contained grease and most of the suspended matter remaining after preliminary treatment. The grease is then mixed with hot water and re-machined, while the water portion of the wastes with soluble soaps and remaining grease and organic matter is either discharged untreated, or treated in another way.

The use of subsiding tanks to remove suspended matter is disadvantageous because much grease is entrained with the sediment and lost, while long storage introduces fermentation which gives the recovered grease a bad odor and high color, consequently lowering its selling price. Because of these disadvantages, primary centrifugal machines, of which the horizontal machine (Fig. 3) is a good type, have come into use. These machines are self-cleaning, and contain a pointed cutter which traverses the bowl of the machine like a lathe tool, and removes the sludge cake from the machine. The cakes fall into a hopper and from this into a chute which delivers them to a bin or conveyor convenient for disposal. These machines, while costly, are efficient.

The re-use of the effluent from the centrifuges works for economical scouring and a higher recovery of grease.

Chemical Treatment.—Chemical treatment, if required, may range from carbonation of kier liquors to preparation of waste for final disposal.

For the coagulation and precipitation of the wastes, four general groups of chemicals are used, namely—

(1) Acid to coagulate fatty acids and certain other colloids.
(2) Ferrous sulfate and lime, with or without aeration.
(3) Ferric chloride or sulfate, with or without lime.
(4) Sulfate of alumina, with or without clay.

When treating textile wastes with coagulants, one should remember that the scourer, bleacher and dyer have purposely added dispersants which increase the amount of colloidal matter; consequently, large doses of chemicals are required to overcome these inhibitants, and sometimes clay or similar absorbents and various de-colloiders, like calcium sulfate, must be added to promote flocculation.

The cost of chemicals must also be considered. According to the engineers and chemists of the Connecticut State Water Commission,[5] chemical treatment may be expected to cost from $100 to $200 per million

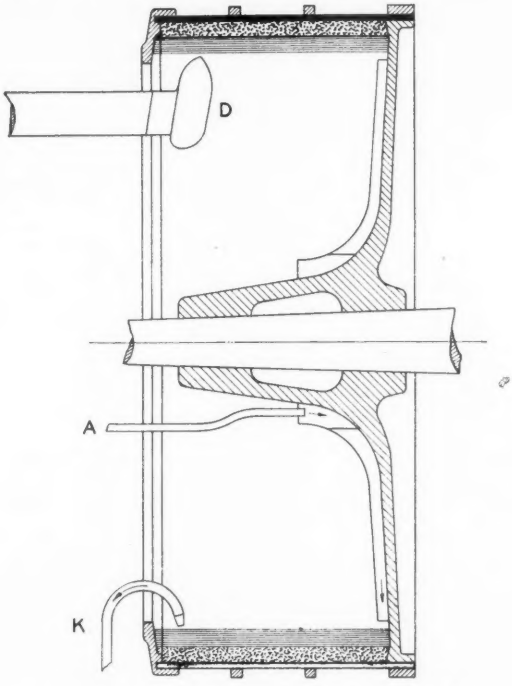

FIG. 3.—Cross section of horizontal centrifugal clarifier.

gallons. This means that a plant treating a million gallons a day must spend from about $25,000 to $50,000 a year for treatment.

A recent study made for a finishing plant which treats 1.255 million gallons of waste daily showed that carbonation of kier liquor and treatment of the whole waste with 2500 lb. of ferric chloride and 6300 lb. of lime per million gallons would produce a fair effluent and a large volume of sludge—10 per cent of the volume of waste.

The chemicals would cost $30,000 a year in addition to carbonation; so, for this reason and because batch treatment would be required under careful supervision, attention is being given to carbonation, subsidence and biological treatment.

It is possible that a better way of treating kier liquor is to add ferric

chloride or sulfate and then reduce the pH value to about 2.0 by the addition of sulfuric acid. Coagulation and clarification follow rapidly. Here again, the cost of chemicals enters; also, a voluminous sludge.

Sludge Handling.—With chemical treatment comes sludge handling and with it a bulky sludge loaded with grease, gums and gurry. There-

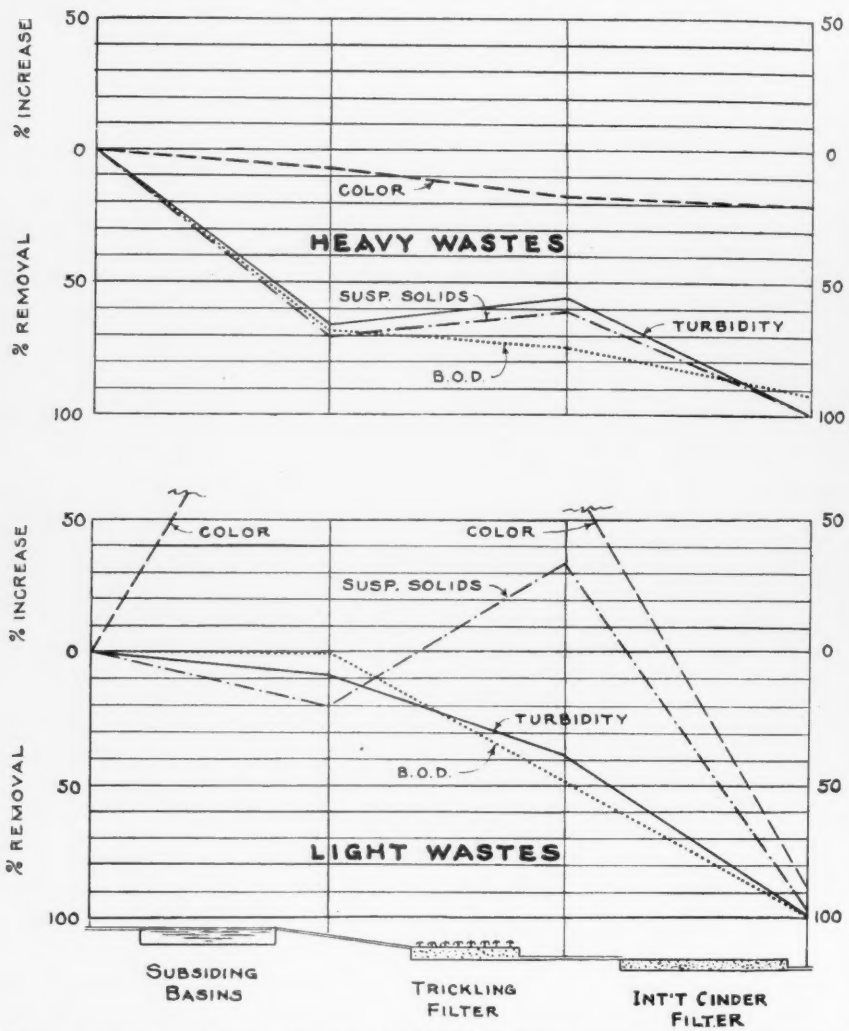

FIG. 4.—Progressive changes in character of finishing plant wastes at various stages of treatment.

fore, ample drying bed area or filter capacity must be provided. Furthermore, the sludges from some of the wastes may not be dried economically on filters and in a few cases it is even cheaper to pump or haul away the undried sludge to lagoons on waste land than to try to dry it on and remove it from sand beds.

Bed Treatment.—Properly prepared wastes may be treated on trickling filters at rates of 2 m.g.a.d. or less, but in the case of bleachery, dye house and many another waste, secondary treatment is necessary for a high degree of purification.

Results of treatment by the trickling filter are meager but the treatment serves to overcome the effects of sterilizing the waste in the total volume and to facilitate subsequent treatment whether biological or chemical. (See Fig. 4.) In this connection, it is hoped that results of

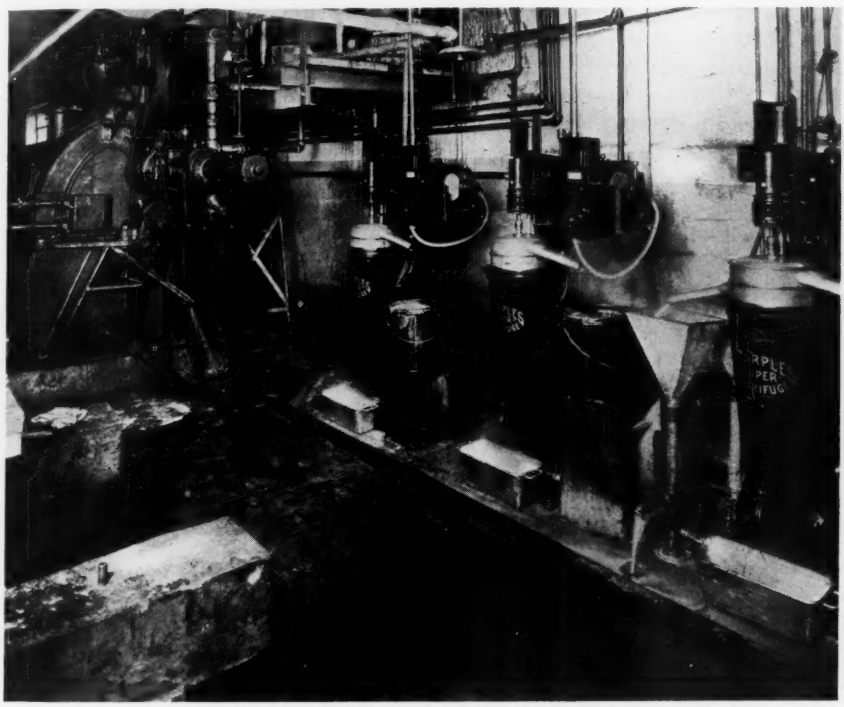

FIG. 5.—One 48 inch solid basket horizontal and three Sharples super centrifuges on recovery of wool grease from wool scouring liquor.

trial of a high rate "Trickling Aero-Filter" [11] at a finishing plant will be forthcoming. The recirculation of the wastes through the filter in this way may so increase the time and aeration factors as to overcome the effects of the inhibiting constituents before the waste leaves the filter and thereby improve its performance.

Experiments with the activated sludge process by the writer's firm at the Cranston Print Works (R. I.) showed that the wastes were so low in suspended matter that sludge could not be kept in the tank. However, when the suspended matter was weighted with clay the process was effective. The cost of clay, however, would have been considerable.

The activated sludge process promises much for the treatment of textile wastes both for preliminary and final treatment because the degree

of oxidation may be controlled and because of the high concentration of certain wastes. It would seem to be particularly advantageous where the wastes contain sulfur or vat dyes or other reducing substances, the treatment of which is furthered by aeration.

References.—Few references are given with this paper, largely because of the complete bibliography in the Geyer-Perry report.

Summary

In writing this review, which is by no means exhaustive, the writer has tried to emphasize that the necessities of the body of water or the sewerage system receiving textile waste should determine the treatment thereof; that each case is individual, complicated and requires preliminary study before design; and that recovery and re-use within the plant and proper treatment outside are essential for the efficient and economical disposal of textile wastes.

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Operators' Reports and Suggestions

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SMALL SEWAGE TREATMENT PLANTS IN CALIFORNIA *

THE WASCO TREATMENT PLANT

By Tipton Mathews

Water Superintendent and Operator, Sewage Treatment Plant

The Wasco Public Utility District, situated in Kern County, was created in 1925 and a water system was built immediately following the formation of the District. In the year 1936 it was thought advisable for the District, on account of the industrial wastes from the creamery and the trouble the creamery was having with the disposal of the wastes, to build a sewer system.

It was impossible for the District to raise sufficient money to build the sewer system and disposal plant without Federal aid. A preliminary study was made and it was found that a bond issue of $90,000 could perhaps be passed and a grant of $61,363 could be obtained from the Federal Emergency Administration of Public Works. The bond issue was voted in August, 1936, and in October, 1936, the District retained the firm of Koebig and Koebig, Consulting Engineers, 458 South Spring St., Los Angeles, to design and supervise the construction of a sewer system and sewage disposal plant for the District.

A permit was obtained from the State Board of Health early in December, 1936, for sewage treatment to consist of sedimentation, separate sludge digestion, burning of sludge gas and chlorination for odor control, the effluent to be disposed of by broad irrigation over a 40-acre tract three miles from the business center of the District.

The plant was designed for a domestic population of 1500 plus trade waste equivalent to a population of 4,500. The maximum design flow is 0.6 million gallons per day.

The raw sewage, after coarse bar screening, enters the wet well from which it is pumped to a clarifier using Dorr mechanism with central feed, 35 ft. diameter with 8 ft. side wall depth. At the maximum flow a detention period of 2.3 hours is provided. Surface floating material is removed by a continuous skimmer.

The clarifier effluent, following chlorination, is disposed of by surface irrigation on the 40-acre tract with no nuisance created by odors. The

* Presented at the Eleventh Annual Spring Conference of the California Sewage Works Conference, Visalia, April 14, 1939. The following four papers, by Messrs. Huth, Johnson, Chitwood and Holfelder, were also presented at this meeting.

effluent has built up the land from very sandy soil without much humus to where it is now raising good crops.

The sludge and scum are removed from the clarifier and pumped to the multdigestion system. The primary and secondary digesters, which are covered, are arranged in series, each of 20 ft. diameter and 20 ft. side depth, to provide digestion allowance of 2 cu. ft. per capita based on the total estimated population equivalent. The primary digester has a rapid stirrer and the secondary tank is built as a gas holder. Supernatant liquor is returned to the wet well.

The plant was put into operation in August, 1937, and was turned over to me to operate a short time afterward. Then the fun started. It was my first experience in handling a plant of this kind and I thought I had learned everything from the engineers, so depended on the instruction books that were left by the equipment companies. However, I found everything in the books but what I wanted to know. I prayed a little, scratched my head and went to work in earnest to keep things going. It was like Christmas with a stream of gifts, neckties, silk socks, toothbrushes and other articles too varied and too numerous to mention.

I could not understand why the engineers had put a bar screen in front of the wet well which did not operate automatically but it did not take me long to find out the logic of that because if I did not go down to clean out the screen I would not go near the plant, so now I make it a habit to visit the plant twice daily, 5:00 A.M. and between 2:00 and 4:00 P.M. to clean off the screens, burn off the gas at the same time and pump sludge about 35 minutes. After pumping, the agitator is operated one hour.

A peculiar thing has happened on the paint job. After operating about three months finger prints that were made during the time of construction were noticed coming through the paint on the roof rafters of the pump house.

So far we have not experienced any trouble and it has been a pleasure to operate the plant. The only time the plant throws off any odors to speak of is when I pump sludge from the clarifier. 700 cu. ft. per minute of air is pumped automatically by electric fan when the pumps turn on or turn off, when the doors of the pump house are opened, and when the lights are turned on, which seems to relieve the odors in the plant to such an extent that I have not yet found it necessary to chlorinate.

The sludge in the secondary digester is drawn off about once a month onto sludge beds where it remains until dry and ready to be used for fertilizer. At present we have an offer from a Bakersfield concern for the purchase of the sludge for fertilizer. It was about thirty days after the first connections were made that sludge began to appear at the plant. At present we have 560 connections to said sewer system.

As potato raising is one of Wasco's largest industries we have 14 washers. These washers when operating use 450 gallons of water per minute. Each washer washes about one carload of potatoes per hour, which gives quite an increase of sludge at the plant, mostly potato skins and some soil. The mud is the only thing that must be watched closely

as it settles to the bottom of the tanks and makes the sludge heavy and hard to draw off. In that case we draw off sludge more often and that takes care of the potato problem.

When the plant was first put in operation there were only three washers and an ordinance was passed that all potato washers should build a sufficiently large settling tank to settle out all mud so it would not get into the sewer. I guess I have been a little lax in enforcing that ordinance.

Tests were taken at the plant at 3:00 P.M. Saturday afternoon, March 25th, immediately following sludge pumping and the results are as follows:

	Raw Sewage	Primary Effluent
Temperature ° F.	69	69
pH	6.9	7.0
Suspended Solids P.P.M.	150	135
Pct. Reduction, Susp. Solids		10
B.O.D., P.P.M.	240	200
Pct. Reduction, B.O.D.		16

Overflow, Primary Sludge Digester
Pct. Moisture 98.4 Pct. Volatile Matter 65.9
Digested Sludge, Secondary Digester
Pct. Moisture 85.0 Pct. Volatile Matter 52.4

These are the first tests taken since the plant was put in operation. Normally a good effluent is produced. The reason for the effluent being so high in B.O.D. and suspended solids is that when the samples were taken I had just finished pumping sludge from the clarifier to the digester.

Since the design of the plant the population of Wasco has increased from 1,500 to 3,800. An area of one and one-half sections of land comprise the Wasco Public Utility District.

From my experience in the operation of the plant I do not see how it could be improved upon if given proper attention. So far it has been trouble free. The water that leaves the plant is used for farming purposes on the 40-acre tract where the plant is situated.

THE VISALIA PLANT

By Norman A. Huth

City Engineer, Visalia, Calif.

The Visalia Disposal Plant consists of separate sludge digestion and trickling filters without secondary clarification or any means of sterilization.

This type of treatment was decided upon after a careful study of the old plant and of the existing conditions near the sewer farm and within the city. The city owns a sewer farm of 160 acres located approximately three miles west of the town. The farm at one time was quite isolated, but during the past several years a considerable number of homes have

been constructed in this area. Also one of the state highway laterals was built along the north boundary line of the farm since its purchase. It was therefore decided that the design of the new plant should eliminate, as far as was practicable, all possible nuisances. The old plant consisted of an Imhoff tank with auxiliary sludge storage capacity, inadequate sludge drying beds and broad irrigation for disposal of the effluent. This plant was considerably overloaded, especially during canning season. The uncovered tanks and gas vent areas were a source of fly and odor nuisance. The ponding of unstable effluent used for irrigation purposes was another source of bad odors.

The City of Visalia is essentially a residential city. It has experienced a steady growth in population of from 4,550 in 1910 to 7,263 in 1930, the present population being estimated in excess of 10,000. The only additional territory which probably will be annexed to the city has a total area of 160 acres with an estimated population of 2,000. There are approximately 40 miles of sewers, most of which are below ground water levels or adjacent to creek channels, and, of course, subject to infiltration. Sewer gaugings taken over a period of 16 days showed an average flow of 1,600,000 gallons per day, with a maximum hourly flow at the rate of 2.6 million gallons per day and a minimum of 750,000 gallons per day. It was estimated that of this amount at least 500,000 gallons per day was infiltration. The water supply for the city is not municipally owned and is not metered. The per capita water consumption exclusive of infiltration is estimated at 120 gallons per day. Chemically, the water is normal, although comparatively low in sulfates.

The biggest problem from a sewage treatment standpoint, however, are the Visalia Packing Company and the Knudsen Creamery. The 1937 pack of the Visalia Packing Company consisted of approximately 6,700 tons of peaches, 200 tons of apricots, 500 tons of nectarines and 900 tons of spinach. The creamery has a capacity of 80,000 pounds of milk per day.

In 1930 a report prepared by Mr. A. E. Reinke of the California State Board of Health presented a picture which was definitely not optimistic as far as the disposal of the canning wastes was concerned. His report states:

"Peach canning wastes entering the sewer cause a layer of peaches and peach fuzz to collect on the settling compartments of the Imhoff tanks, which if not skimmed daily, causes considerable fly and odor nuisance." This information together with our own experience and the records of experiences of plants in other cities, attempting to treat this peach waste, was definite warning that trouble would be encountered unless adequate facilities were provided for skimming and digestion of this waste. It was for this reason that skimming was installed in the primary clarifier, also scum stirring in the heated digestion tank.

Investigation showed the cannery flow to be approximately 0.58 m.g.d. and the population equivalent 3,000 persons.

The products of the Knudsen Creamery are cheese, butter and cream. It is estimated that the wastes of the creamery are between 30,000 and 40,000 gallons per day and are equivalent to approximately 1,000 people.

Based on the above data, this plant is designed for a future average flow of 3.12 m.g.d. and a population equivalent of 20,000. From weir gaugings it was determined that the maximum hourly flow would exceed the average by 60 per cent.

A careful estimate made by the consulting engineers showed that incorporating the old Imhoff tanks into the new design would effect a saving to the city of $12,300 and would produce just as modern and usable settling and digestion tanks as entirely new ones. However, due to the peach wastes it was felt that additional digestion capacity should be provided for, hence, the additional heated digester was added.

The designing engineers considered two types of treatment as being suitable for meeting the above conditions: *i.e.* activated sludge or trickling filters. The construction costs would have been slightly greater for the activated sludge plant and the maintenance costs would have been at least twice as great as for the trickling filter type of plant. The main reason, however, for deciding in favor of the trickling filter plant as constructed instead of the activated sludge type was because of the high percentage of industrial wastes during the canning season and the probable difficulties that would have been encountered in activated sludge treatment.

As to plant capacities the primary clarifier will provide a detention period of 65 minutes for the future maximum hourly flow. The digestion capacity is 3.15 cu. ft. per capita. The trickling filter will be dosed at the rate of 4.35 million gallons per acre per day. However, since this is a continuous and not an intermittent dosage, the load on the filter will amount to approximately 2,800 people per acre foot. The sludge drying beds have an area of 0.8 sq. ft. per capita.

The primary clarifier is equipped with Link-Belt "Straight-line" clarifying equipment and Currie air skimmers. The equipment in the heated digesters as well as the sewage distributors was furnished by the Dorr Company. The pumps pumping the sewage from the primary clarifier to the distributor were furnished by the Kimball-Krogh Company and are driven by an Enterprise gas engine and a Sterling "Speed-trol" electric motor, respectively. The float control of each is so designed that continuous pumping, proportioned to the inflow, is assured. The electrically driven pump is so designed as to act as a stand-by for the engine driven pump. Measurement of the sewage flow is determined and recorded by a Morey-Jones electric flow meter, operated from a Venturi tube in the pump line. Sludge is pumped by a Carter sludge pump. The piping for all sludge pumping is brought to a control manifold where by proper valving, sludge may be pumped from the primary clarifier to the heated digestor, to the secondary digestors, or direct to the sludge bed. The manifold is so designed that sludge may be pumped from, or to, any point, thus providing for cleaning of suction lines.

The plant was built under a P. W. A. Grant and the Currie Engineering Company designed the plant and supervised the construction.

THE DELANO PLANT

By Glen Johnson

Water Superintendent and Operator, Sewage Works, Delano, Calif.

The City of Delano is essentially a residential city with a large contributing agricultural area. The city experienced a particularly rapid growth between the census years 1920 and 1930, its 1920 census being 805 compared to 2,630 in 1930. It is estimated the present population is 4,000.

During 1922 plans were prepared and bonds voted under the 1915 Bond Act for an extensive sanitary sewerage system and disposal plant. Two hundred acres of land were purchased 1.5 miles west of Delano in an area of poor soil conditions. To this day the region is sparsely settled and very well adapted for use as a sewer farm.

This disposal system consisted of an Imhoff tank and distribution of the effluent upon the sewer farm. The tank, 33 ft. square, was originally planned for a population of 2,500. With the steady growth of the city, the tank became greatly overloaded. Floating scum and sludge on the surface of the sewage promoted the breeding of flies and the effluent contained a large amount of finely divided solids.

Sludge was handled by gravity only, hence large pits were located on the north and south sides of the tank. With increased use it became impossible to dry out this sludge and it was necessary to scrape out this unsavory mess with men, mules, and a Fresno scraper and dry it on the ground around the plant.

Last May, by order of the Council, I asked C. G. Gillespie, Chief of the Bureau of Sanitary Engineering, to make a personal inspection of the disposal plant and give us his recommendations. His answer was so complete and to the point that I take the liberty of including it in this report:

Dr. T. L. Meehan, Mayor
Delano, California

Dear Doctor Meehan:

Confirming our conversation of last week in the matter of the adequacy of the city sewage tank and sewage disposal generally, I wish to say the city is fortunate in having an unusually well isolated place for sewage disposal and I cannot see that more than simple sewage clarification is needed. That is the purpose of the present Imhoff tank. However, in common with tanks designed in the period this one was built, it is now greatly undersize. It is hardly sufficient in capacity for half the population. The result of this is to impair clarification to some extent and more seriously to reduce the time of sludge digestion so that the sludge is sour and troublesome throughout the tank. For a long time this has been one of the meanest and most troublesome of tanks from an operator's viewpoint.

There are several ways the plant can be worked over to utilize more modern ideas. The principal features I would recommend are:

1. Ample space for sludge digestion or in lieu of this, put hot water heating coils in the new tank so that sludge digestion will proceed in winter as well as summer. Coils cannot be adapted to the present tank. It is possible, however, to convert the

present tank into a heated digester and to simply add a new clarifier. Or it may be preferred to make a new and much larger tank of the same type as at present.

2. Make it possible to put the digested sludge onto sludge drying beds, built at or above ground. The present sludge beds are in a hole and sludge does not drain. This means sludge pumping at least is necessary.

Yours very truly,

BUREAU OF SANITARY ENGINEERING

By C. G. GILLESPIE,
Chief

After this report, action followed shortly. The Currie Engineering Co. was engaged to prepare plans for a new sewage disposal plant, and to make application to the P.W.A. for a grant covering 45 per cent of the construction cost of such a plant as well as the installation of 7380 ft. of cement pipe storm drains, with 18 manholes and 28 catch basins, 6294 ft. of 6-in., 3874 ft. of 4 in., and 690 ft. of 2 in. cast-iron water mains. These mains were laid to effect circulation and increase pressure, particularly for fire protection. Also a complete Gamewell 30 station fire alarm signal system using a Diaphone Air Horn as the alarm signal.

In due time, our grant was approved, and due to the fact that our funds were secured from our surplus, no time was lost in floating a bond issue. Pettijohn and Haddican, of Delano, were the successful bidders. Cost of total project, $53,392.20; disposal plant, $22,363.00. To this must be added 8 per cent for engineering and superintendence.

Our engineer planned the plant with the suggestions of the State Board of Health in mind.

Briefly the plant is comprised of the following units: A primary clarifier to provide one hour detention on the maximum flow from a future population of 8,000, a primary digester with a sludge capacity of 1.0 cu. ft. per capita, and a secondary digester with a sludge capacity of 1.5 cu. ft. per capita, a sludge bed well drained and easy of access, a sludge pump with provisions for removal of skimmings and solids from the primary clarifier to the digesters and on the sludge beds, and other necessary operating equipment, including water system, gasometer, and heating equipment for the primary digester. No equipment has been added for further purification of the settled effluent as the isolation of the sewage farm is sufficient to provide adequate spreading of the effluent without its becoming a nuisance.

I shall explain briefly the construction of the various units and the equipment used.

1. The primary clarifier is circular, 32 ft. in diameter by 7 ft. side depth. The capacity is 42,113 gallons. The Dorr Company supplied the equipment, which consists of a Type T clarifier mechanism, with steel support beams with walkway and railing from one edge of tank to center, worm gear drive head with gearmotor and chain drive, center shaft with tie rods and raking arms, influent well and pipe, movable skimming arm, air skimmer pipes suspended from walkway, and air blower. A 1.0 HP. motor drives the raking arms and a direct connected 3 HP. motor operates the fan.

2. The primary digester is a circular tank 26 ft. in diameter by 20 ft. 3 in. three side depth. The capacity is 80,424 gallons. The equipment is a Type A Dorr Digester Mechanism, which includes roof support beams, stationary scum breakers, worm gear drive head with gearmotor and chain drive, center shaft with scum breaker arm, and sludge scraper arm driven by a 1.0 HP. motor. This tank is heated to speed up bacterial action, particularly in cold weather. Six sets of vertical heating coils are equally spaced around the circumference of the tank. Thermostatic control maintains an even temperature.

3. The secondary digester is a square tank 33 ft. on a side, divided into two sections by a central partition. This is the old Imhoff tank with the baffles and dividers removed and capped with a reinforced concrete cover. Whether the use of the old tank saved much money is problematical, however, the psychological effect is good, inasmuch as we did not destroy a $7000 plant. There are no moving parts in the secondary digester.

4. The control room contains a Barnes-Dorco type TX 306 Sludge Pump driven by a 3 HP. motor. The manifold has five double sets of valves. It is simple to operate and extremely flexible.

This room also contains the switch board, water pressure tank, and Bryant Water Heater, and ¾ HP. hot water pump. To supply gas for the water heater, the primary digester and each section of the secondary digester are equipped with gas collectors, which are connected to the gas holder 4 ft. in diameter and 5 ft. high.

5. The last unit is the sludge bed, which is 50 ft. long by 80 ft. wide. The bed is drained with 6 in. tile and is built up of pea gravel and sand.

To provide information relative to daily flow of sewage for our engineer, a weir was set up in the effluent ditch last June.

The readings for 24 hours, from 7 A.M. June 11, to 7 A.M. June 12, were as follows:

	Time	Rate, gal. per min.
June 11	7 A.M.	121.5
	10 A.M.	210.0
	1 P.M.	261.0
	4 P.M.	261.0
	7 P.M.	236.0
	10 P.M.	288.0
June 12	1 A.M.	315.0
	4 A.M.	142.0
	7 A.M.	121.5

Readings were taken for a week and it was well determined that the above results were typical. From these readings we find an average flow of 218 gallons per minute or 77 gallons per capita per day. This per capita flow is higher at this particular period than during cool weather, due to the various types of cooling systems which do not recirculate the water. This flow is almost entirely from residences and stores. We do not have a creamery or manufacturing plants.

The location of the plant was, of course, fixed, as the old Imhoff tank was to be used. The height of the clarifier was also fixed by the outfall

sewer line. This line at the railroad tracks on Cecil Avenue is 14 ft. deep, at the sewer farm it is 1.5 ft. below the surface—a distance of 10,858 feet. The grade of this line runs from .0018 to .002.

This outfall sewer is a 15 in. concrete pipe which was laid during the winter of 1922–23. A year ago last January we found a serious condition existing in the arch of this pipe due to the low gradient and the length of the outfall. Hydrogen sulfide gas was forming in the sewage and oxidizing to dilute sulfuric acid, which had eaten the cement away to a dangerous point.

An application was made to the W.P.A. for a project to repair this line. The project was approved to provide for re-capping the outfall line with a cement crown not less than 2 in. thick and extending below the center of the pipe on either side. This job was successfully completed at a cost to the City of $2,659.22 and to the W.P.A. of $21,538.00. We are pleased to acknowledge our indebtedness to the P.W.A. and the W.P.A. for giving our City the opportunity to secure adequate and sanitary sewage removal and disposal.

Our City Council, composed of the following men, Mayor T. L. Meehan, B. F. Stradley, A. S. Cole, O. T. Mast, and John J. Graham, is to be congratulated for having the vision and the courage to avail themselves of the opportunity to provide the City of Delano with these essential improvements.

In closing, I would like to pay tribute to a man who has served the City of Delano long and well. He fought the old Imhoff tank when it took plenty of courage and hard work. I refer to a man many of you know as he has attended these meetings—A. Ackerman.

TEHACHAPI SEWAGE TREATMENT PLANT

By C. S. Chitwood

Water Superintendent and Operator, Sewage Treatment Works

Tehachapi is located in the mountains of Kern County at an elevation of 4,000 ft. and has a population of 1,000 inhabitants. It is one of the oldest settlements in the State of California.

In January, 1937, the city engaged the firm of Koebig and Koebig, Consulting Engineers, 458 South Spring Street, Los Angeles, to prepare a report on the proposed sanitary sewer system and disposal plant, which report was used as a basis for submitting the question of bond issue for $31,000 to the electors. The election held in February, 1937, carried by the overwhelming majority of 10 to 1, which indicated the wholehearted support of the citizens in this worthy project. Following this the engineers prepared and submitted to the Federal Emergency Administration of Public Works an application for a grant of $25,363, which was approved during the early fall of 1937.

The contract for construction of system and plant was awarded in November, 1937, and construction started almost immediately. Project was completed and ready for operation in May, 1938. The construction

was carried on successfully and without excessive delay, although there were many days during the winter period when snow covered the ground and prevented steady work.

The plant site of 10 acres, situated about one mile from town, was donated to the city by one of the substantial taxpayers. All sewage is collected and carried to the plant and through the plant by gravity. The plant consists of an Imhoff tank and a trickling filter, with the effluent being lagooned on the 10-acre tract before it is percolated into Tehachapi Creek. General data on the plant follow:

Design population, Imhoff tank 2500
Design flow, Imhoff tank ..... 0.015 M.G.D.

Plant units

Rotary trickling filter
- Design population filter, 1800
- Size of filter, 66 ft. dia. by 6 ft. rock depth
- Rate of application, 1.4 M.G.D./acre

Imhoff tank, size 22 ft. wide by 28 ft. long
- Sedimentation chambers 28 ft. by 15 ft. by 4 ft. = 1724 cu. ft. above sloping partitions
- Detention period 2.06 hrs.
- Sloping partitions 1 ft. 3 in. on 1 ft.
- Sludge chamber 22 ft. by 28 ft. by 2 ft. 7 in. straight wall below bottom of gas deflector
- Depth of hopper 10 ft. 6 in. = 3747 cu. ft. of sludge storage, or 6 months storage.

The sewage is entirely domestic with little variation in content throughout the year except for temperature variations. The seasonal temperatures vary from warm weather to 10° above zero during the winter.

Suspended solids in the raw sewage vary from 200 to 250 p.p.m. and B.O.D. from 200 to 250 p.p.m. A detention period of 2.06 hours is provided in the longitudinal settling tank, the efficiency of settling being as high as 60 per cent at normal flows. A northerly wind keeps the scum drawn to the scum chambers on the effluent side of the tank thereby not allowing unsightly scum conditions. The gas deflector prevents the majority of the digesting sludge rising to the surface from entering the main settling compartment with the absence of the usual discoloration and odors of Imhoff tanks.

Although the B.O.D. reduction is not so high as the suspended solids removal the greatest load of solids is removed for efficient filtration treatment.

The filter is dosed intermittently and by providing an ample capacity of air in the features of design all septic conditions have been eliminated in the filter, which turns out an effluent crystal clear, with a slightly musty odor and with some sludge deposit. The only life visible to the eye outside of a thin top coating of bacterial slimes is a few filter flies and small larvae discharged from the filter. The B.O.D. on the filter effluent is 70 p.p.m. and suspended solids are also 70 parts per million.

Evidence of an occasional filter overload to produce septic conditions is seen in the lagooning of the effluent. A few bubbles of gas can be seen rising from the bottom but these are so few there is no danger of a nuisance ever being created.

One of the worst operating difficulties is the freezing temperature, which is hard on the little outside equipment at the plant. During the one winter in service the concrete stood up very well. The sludge that has been drawn from the bottom of the primary tank has reached a good stage of digestion for this type of installation. No septic odors have been prevalent in the sludge and the dried sludge has no odor whatsoever.

The location of the plant and the natural topography of the country afford an entirely gravity system with no mechanical equipment necessary. No odors are noticeable on account of the excellent wind conditions. The wind blows through the draw from the northwest to the southeast almost continuously, which aids filter aeration. The type of its construction allows the air to pass through the filter bed.

The tanks are so designed that they have ample capacity for present and future population. There is no industrial waste to be provided for and no anticipation of any in the future.

Samples of sewage and sludge taken on March 25, 1939, at 10:00 A.M. showed the following results:

	Raw Sewage	Effluent from Imhoff Tank	Filter Effluent
Temperature, ° F.	58°	56°	56°
pH	7.7	7.5	7.5
Suspended solids, p.p.m.	210	85	70
B.O.D., p.p.m.	220	170	70
Pct. reduction susp. solids		59.5	66.7
Pct. reduction B.O.D.		33.0	68.2

These were catch samples only. There was no offensive odor from the filter effluent.

The plant practically operates itself but like all plants needs attention.

Since this improvement has been completed the City has shown considerable growth and is fast becoming a trading center for surrounding territory. Likewise by reason of the favorable climate in the summer time and the altitude, many people are making this locality their summer home and resort.

SEWAGE WORKS IMPROVEMENTS FOR THE CITY OF BAKERSFIELD

By J. Holfelder

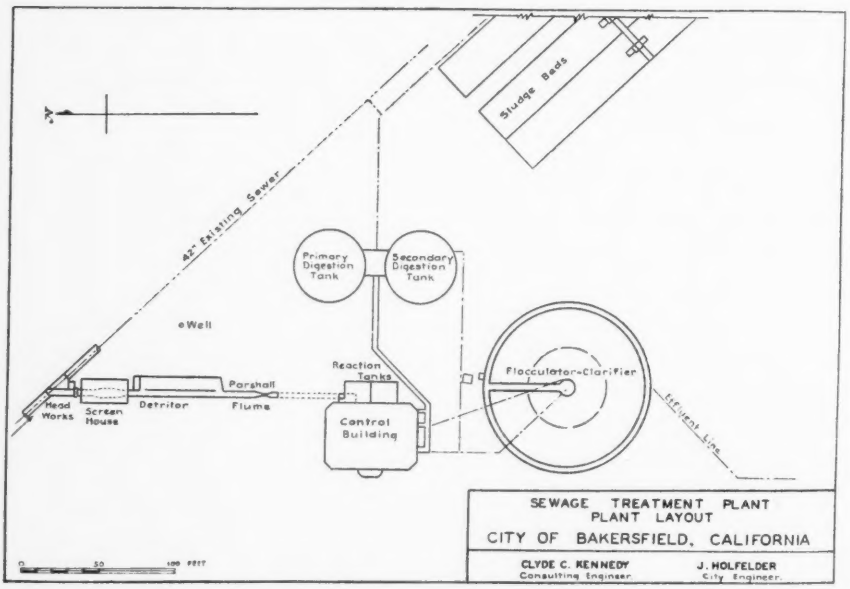
City Engineer

The program of sewage works improvements for Bakersfield comprises an intercepting sewer, a sewage pumping station and a sewage treatment plant.

Three separate and comparatively small areas in the southwestern portion of the city have been served by local collecting systems of sewers to a pumping station in each of the areas for lifting to the nearest gravity sewer.

The new intercepting sewer, a mile and a half long, constructed of 15-, 18- and 21-inch diameter concrete pipe, will intercept the collecting sewers at each of the older pumping stations and empty into the wet well of the new pumping station. Although the total lift of sewage will be somewhat greater from the one sump than from the former three, the load factor at the new plant will be improved through flattening of the peaks of flow and economy will be effected by reduction of the number of pumping units and accessories.

Other important results to be obtained from the concentration of the pumping at one plant are: (1) the restriction of peak discharge to that of the capacity of the one plant as against a peak due to possible coincident capacity discharge from the former three plants; (2) the shortening of the time of detention in the sump between periods of pump operation, and (3) opportunity for chemical dosage of the sewage for odor control and to retard septic action, not only in the pumping station sump but also in the main outfall sewer into which the pumps discharge.



The new pumping station will have Scott-Darcey Universal type of chlorination equipment for the production of solutions of chlorine or chlorine-iron and the feeding thereof to the sewage as it enters the pump sump, or at the trunk line outfall sewer at the point of pump discharge thereto, or at both places.

Operation under the conditions of actual flow will demonstrate the amount and quality of dosage, as well as the point of application, that will best control odors at the pumping plant, retard septic action in the trunk sewer, and keep the sewage as fresh as possible as it enters the treatment plant. The pumping equipment is the Chicago Pump Company's "Flush

Kleen" duplex unit system, consisting of two vertical pumps with interconnecting piping, strainers, valves, automatic float control and alternator.

Three miles east of the pumping station, and more than four miles from the center of the city, the 42-in. trunk sewer enters the treatment plant. The average slope of the ground surface of the tract, generally to the southeast, is approximately 7 ft. to the mile.

In order of sequence of flow through the plant, the several structures are: by-pass and flood control structure; screen house and screen; detritor; Parshall flume; control building containing pump sump and pumping units; reaction tanks with chlorine solution equipment, gas burning water heater, water supply and circulation pumps and accessories, sludge pumps, laboratory and provision for future installation of gas engine driven electric generators; flocculator-clarifier; sludge digestion tanks and sludge drying beds.

The control structure which diverts the sewage flow from the existing sewer to the plant is provided with gates for re-diversion back to the old channel, in case of necessity for by-passing the plant, and an overflow weir for the automatic by-passing of possible flood flow in excess of any desired load on the plant.

In the screen house a mechanically cleaned bar rack with ¾-in. openings is automatically operated by floats. The cleaning rake elevates the screenings to a triturator so located that the shredded screenings may be drained and chuted to a screenings buggy for transportation to the scum sump adjacent to the clarifier, whence together with the scum they will be pumped to the primary digester.

Provision is made for optional discharge of shredded screenings direct to the sewage stream below the bar rack. Grit removal is provided in a detritor channel double the width of the main sewage conduit and of a depth sufficient to reduce the velocity of flow to approximately one-third of that in the main conduit under the conditions of flow when grit removal will be required. A motor-operated rake will discharge the settled grit to a hopper outside the detritor. The rate of flow of sewage is measured in a Parshall flume constructed in the channel below the detritor and with recording instruments in the control house.

The invert of the sewage channel entering the control house is 15 ft. lower than the selected elevation for the clarifier overflow weir. The sewage sump has a storage capacity of 50 minutes, based on the average daily flow. This will provide emergency storage in case of a power failure. The pumping plant is designed to operate automatically under the conditions of the varying rates of daily flow, with the sewage level at all times below the half capacity of the sump. The pumps are the horizontal centrifugal type located in the pump room adjacent to the sump, with center line of pump 1 ft. above bottom of sump.

The present pump installation consists of two identical units of 2500 g.p.m. capacity with constant speed motors, and two units of 1250 g.p.m. capacity at full speed, with vari-speed drive. One of the larger pumps is expected to operate continuously, or nearly so, its capacity being very close to the average minimum daily sewage flow. Float controls are

designed to actuate the vari-speed driven pumps at flows greater than the capacity of the constant speed unit. The second constant speed unit is designed to operate alternately with the first unit. Provision has been made for a third constant speed unit of 2500 g.p.m. when the sewage flow increases.

In the control building will be installed the Scott-Darcey Universal type chlorination unit for dosing with ferrous chloride at the screen-house or pump sump for odor control, with ferric chloride in the line ahead of the flocculation-sedimentation tank for coagulation, and with chlorine for conditioning the supernatant liquor from the sludge digestion tanks and for terminal disinfection, when and if necessary. Also in the building are to be located the sludge pumps, hot water boiler and circulating pump, fresh water pressure tank, and the flow recording gage and control board. Provision for adequate office and laboratory facilities is also included in the building.

Some effort has been made to give a pleasing architectural appearance to the control building without any lavish expenditure of money. In this treatment, glass brick has been employed to produce panel effects.

The flocculator-clarifier unit is 100 ft. in diameter with a center depth of 17 ft. 11 in., and a side water depth of 10 ft., with center feed and circumferential discharge. The central zone 50 ft. in diameter is designed to operate as a flocculating unit and will be equipped with a Dorr flocculating mechanism. The annular ring outside the flocculating unit is the sedimentation unit and will be equipped with Dorr scraping and skimming mechanism. Provision is made for adding ferric chloride to the sewage in the influent line when and if peak load conditions require it for adequate solids removal.

The digestion tanks provide for two-stage digestion with heating coils only in the primary digestion tank. The tanks are each 45 ft. in diameter and 22 ft. deep with a gas holder on the secondary tank to provide for equalizing the gas flow. The necessary interconnecting piping and valves for control of sludge flow are housed in the valve house which connects the digestion tanks. All piping for sludge lines, water lines and gas lines is carried in a pipe gallery between the digestion tanks and the control building.

The supernatant liquor from the digestion tank is carried to the pump line leading from the pumps to the flocculation-sedimentation tank and has provision for chlorine dosage in the line to condition the liquor if it should have a tendency to upset the tank operation.

The sludge drying beds are 25 ft. by 100 ft. in plan. They are provided with a motor-driven belt conveyor and loader which may be moved from one bed to another by means of transfer rails. As a part of the present contract, only four beds are to be constructed. In the layout, provision is made for increasing the number of beds when and as needed.

The water supply for the plant is provided by a well with an automatically controlled pressure system. The outdoor piping system includes provision for adequate irrigation of the grounds. An auxiliary W.P.A. project has been set up to landscape the grounds and plant with grass and shrubbery.

CITY OF BAKERSFIELD
TREATMENT PLANT DATA

Estimated population, incorporated area	31,000
Estimated population, contiguous area	40,000
Estimated tributary population, 1950	45,000
Present sewage flow, average during summer	4.0 m.g.d.
Design sewage flow, average daily	7.0 m.g.d.
Design sewage flow, maximum rate	10.5 m.g.d.
Combined flocculation, sedimentation tank	100 ft. diam.
Detention period, 2 hours at 7 m.g.d. rate of which 30 minutes is flocculating period.	
Digestion tanks, 2–45 ft. diam. 22 ft. deep at 35,200 cu. ft. capacity each.	
Holding period at 7 m.g.d. flow, primary	15 days
Holding period at 7 m.g.d. flow, secondary	30 days
Sewage Characteristics	
Settleable suspended solids, weighted for week	250 p.p.m.
5 day B.O.D., weighted for week	234 p.p.m.

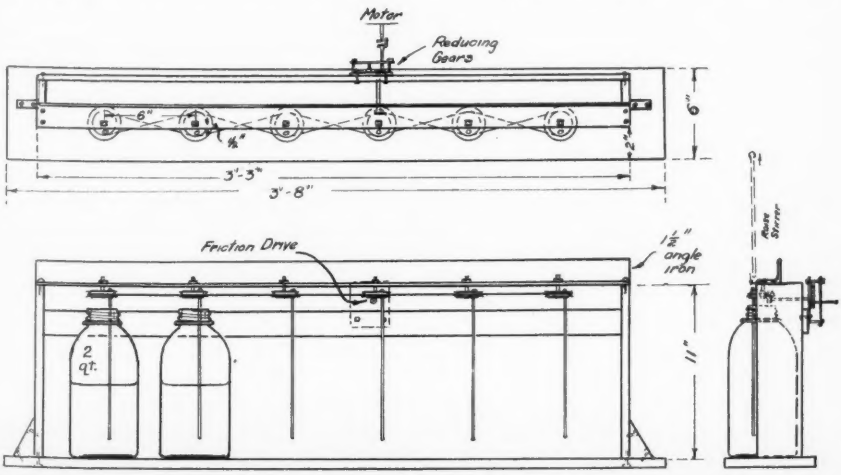
ANOTHER STIRRER

Larchmont, N. Y.
May 29, 1939

Dear Dr. Hatfield:

Your review in *Sewage Works Journal*, **11**, 308 (1939) of stirring devices is of practical interest. Outside of commercial type apparatus, there have been some very effective gadgets constructed.

The sketch indicates a wooden stand supporting an angle iron frame. This is drilled to accommodate bolts which support the "ball bearing" pulleys which are roller skate wheels. The pulley groove is made by



fastening on strips of rubber tubing split lengthwise. The blank faces of the wheels are drilled to take the glass rod stirrers as shown. One end of each rod is heated and upset to form a small knob at the end, upon which the rod rests in position. Two quart "Atlas" jars are used which hold just one liter as measured to the cross bar of the "A." The stirrer is easily raised or lowered since the pulleys are installed so that the holes for the stirrer rods clear the angle iron. The belt may be a piece of string, the friction drive a short length of rubber tubing over the gear shaft. Some speed adjustment is available here by shifting the point of contact. The reducing gears are all out of an old water meter and the motor of an electric fan may be loose coupled with the gear train as indicated. A rate of 50 r.p.m. for the stirrers was thus obtained.

I claim the following additional advantages for the Hotchkiss stirrer: No metal is in contact with the solution. More uniform motion by the eccentric stirrer, without paddle, is obtained throughout the vertical depth of solution. Total cost will depend on local market conditions and labor charges.

Yours faithfully,

HENRY T. HOTCHKISS, JR.,
Supervising Chemist

SEWAGE TREATMENT OPERATION COSTS

From "The Digester" for May, 1939
Division of Sanitary Engineering
Illinois Department of Public Health
C. W. Klassen, *Chief Engineer*
H. W. Wisely, *Editor*

At the outset of this discussion, let it be thoroughly understood that sewage treatment works are built for the purpose of preventing stream pollution and that this should be the primary object of every operator. To accomplish that aim with a minimum of operation expense is also a duty of the operator, but he must not strive for low costs to such an extent that treatment effectiveness is sacrificed.

Operation costs include those expenditures required to make the plant, as constructed, function in a proper manner and to keep it properly maintained. Such costs include salaries and wages of operation personnel, purchases of power and supplies, costs of repairs, etc., and do not include bond retirement, bond interest, or cost of plant extensions.

Note, by W. D. Hatfield, Editor: I think it is a great mistake to leave out the capital costs. Part of the annual cost of sewage treatment is the retirement of bonds and interest. Frequently the deciding difference between activated sludge and trickling filters is weighed by a balance of the annual interest charge against power cost. How then can power cost be included in operation costs and at the same time exclude the item of interest and bonds?

In order for you to operate your plant as economically as possible, it is necessary that you keep suitable cost records, and it is suggested that this

information be obtained from the city clerk or treasurer each month. The various expenditures should be classified under major headings, the ones used most commonly being: (1) Labor, (2) Power, (3) Supplies, (4) Repairs and Replacements, and (5) Miscellaneous (includes insurance, telephone, truck expense, etc.). Of course, special types of treatment plants may require other major items, such as for chemicals used in chemical precipitation plants.

A detailed study of operation costs in 30 Illinois sewage plants (*Engineering News Record*, December 28, 1933), includes the following summarized data on three types of plants:

Type of Treatment	Total Operation Costs		Percentage of Total Costs		
	Per Capita Yearly	Per M.G.D.	Labor	Power	All Other
Activated Sludge	$0.93	$24.00	34	56	10
Trickling Filters (Sewage not pumped)	0.57	10.95	79	4	17
Trickling Filters (Sewage pumped)	0.75	13.85	56	32	12
Sand Filters (Sewage not pumped)	0.47	11.90	86	—	14

Widely varying local conditions result in similar wide variations in operation costs at different plants. Therefore, you need not be surprised if the figures for your plant are greatly different than the above average values. Incidentally, new developments in the field have greatly increased the number of gravity flow trickling filter installations and we are of the belief that such plants at this time will generally show lower operation costs than the table indicates.

A discussion of the principal items of operation cost, with suggestions for minimizing them, follows:

Supervision and Labor.—It is generally best to employ just enough full-time men as will be kept continuously busy with routine work, with extra labor hired as needed. In most plants serving up to 10,000 persons, one or two full-time men are needed and extra help is employed occasionally for moving sludge, maintenance of grounds, etc. Except for larger plants, or where considerable mechanical equipment is used, it is rarely necessary to provide day and night attendance, although the operator must be prepared to put in a few "off" hours during emergencies if his plant is left unattended during the night. Many smaller plants can be operated satisfactorily by one man who can spend 3 or 4 hours on routine work every day with additional time as needed for the occasional larger tasks.

Where sewerage works have been financed by sewer rental charges, those who are unable to pay may be allowed to work off their delinquent bills as extra laborers at the treatment plant. This is done to advantage at Monmouth.

Naturally, the operation personnel required at any plant depends on its type, size, location, etc., and the best way to plan for routine personnel is to develop a schedule of the various duties and adhere to this as closely as possible. We refer you to the daily schedule used by Ray Corr (Woodstock), published in our August, 1935 issue.

Labor and supervision takes about 40 to 80 cents of each operation cost dollar in trickling filter plants, and 35 cents of each operation cost dollar in activated sludge plants. Organization of work and time will minimize such costs in plants of these types.

In sand filter plants, however, labor takes 85 to 90 cents of each operation dollar because such filters must be cleaned manually. Efficiently operated primary settling tanks will lengthen sand filter runs between cleanings, thus saving time and expense, so study and improvements at those units may yield good dividends.

To summarize, "Organize your Work for Low Labor Costs"!

Power.—Power costs also vary widely from plant to plant depending on the amount of mechanical equipment used. Too often, the municipality is inclined to accept the first rate schedule offered by the power company as the most favorable that can be obtained. At several plants using appreciable amounts of power, it has been possible to obtain worthwhile reductions in rates by taking up the matter with power company officials.

Separate power meters on major items of equipment such as aerators and sewage pumps are desirable for checking efficiencies. Sewage pumps should be tested at least yearly and any apparent efficiency loss due to worn parts given prompt attention. Such tests may also reveal faulty discharge piping causing excessive friction losses. Where the inlet to a wet well causes turbulence at pump suctions, entrainment of air may cause the pump to partially lose prime and result in higher costs. Placing of suitable baffles will usually stop this interference.

In activated sludge plants, power purchases take about 55 cents of each operation dollar, hence the need for careful control by the operator. Mixed liquor suspended solids concentrations should be kept in adjustment to the sewage character so that a minimum of air is needed. Advantage may be taken of seasonal changes in sewage character to remove some of the aeration units from operation, as long as the condition of the outlet stream is not jeopardized. Proper maintenance of piping and plates in diffused air plants and of mechanical aeration devices will make for efficient power utilization. High concentrations of dissolved oxygen and nitrates in the plant effluent may indicate that aeration has been carried further than is necessary.

Removal of parts of the plant from service during wet seasons to save pumping or other power costs must be based on good judgment and an operator considering such should always take up the matter with the State Sanitary Water Board beforehand. In general, all parts of the plant should be used at all times, as past experience has shown that the discharge of partially treated sewage during wet weather may result in sludge deposits which exert their worst effects later, in times of critically

low stream flow. Keep in mind that the plant was provided for the purpose of keeping the stream clean.

The advent of the sewage gas engine was an important new development in bringing about reduced operation costs at some plants. Gas engines should never be installed, however, unless a thorough, sound, economic study by a qualified technical advisor shows them to be definitely advantageous. For example, a small engine requires nearly as much attention as does a large one, and the extra labor required may bring the cost of gas power above that of purchased power. Also, when a utility service connection must be retained for auxiliary power following the installation of a gas engine, the standby charge may be so high that it would be best to purchase all power at a slightly more favorable rate.

Good plant operation records yielding information regarding power requirements, gas production, heat requirements, and quality of gas, are invaluable for an economic study on the applicability of gas engines to a plant.

Repairs, Replacements, Maintenance.—This item takes about 5 to 15 cents of each operation dollar. Oddly enough, economy in maintenance requires that you spend to save, since small expenditures for grease, oil, and paint will reduce large expenditures for major repairs and replacements.

Frequent inspection of all plant structures and equipment with prompt attendance to small defects and faulty equipment adjustments will yield dividends. All parts of a sewage plant are subjected to corrosive gases, and if care is not taken, a lot of expensive equipment can be ruined in a couple of years.

Proper lubrication at all times, proper adjustment, and maintenance of exposed gears and bearings free of grit and other foreign matter causing undue wear will delay expensive equipment replacements. Liberal use of paint of the proper type for the intended purpose and applied according to manufacturer's instructions saves concrete, metals and wood. The most economical paint is the one giving best protection for the longest time; not the cheapest one you can buy.

Expenditures for practical tools and equipment for maintenance and repair work may reduce overall operation expense. A power lawn mower, for example, may pay for itself in a couple of years by the saving in labor it affords.

Elaborately landscaped grounds are costly to maintain. Sewage plant sites may be adequately landscaped by hardy, native plants and shrubs, properly located for the purpose and convenient to attend. Be practical in this!

Conclusion

Remembering that the treatment plant was built, after all, to treat sewage and protect the stream, let us all try to accomplish this at the lowest possible cost. Organization of your work, efficient usage of power, attention to small details in maintenance, complete operation and cost records and application of judgment to purchases of equipment and supplies are essential to economical operation.

URBANA AND CHAMPAIGN SANITARY DISTRICT, CHAMPAIGN–URBANA, ILLINOIS

EXCERPTS FROM OPERATION REPORT, SEWAGE TREATMENT WORKS

Fiscal Years,
May to April, 1936-1937 and 1937-1938

May 1, 1938

Frank D. Murphy, *President*
Frank Hudson, *Vice-President*
Harold F. Mooney, *Clerk*

Eleventh Published Report

By C. V. Erickson, *Manager*

Sewage Treatment Works

The plant was placed in operation on November 21, 1924. As then built the intercepting sewers were planned to serve a population of 70,000, and the treatment works a population of 45,000. Treatment units provided included screen, flow measuring weir, primary settling tanks (Imhoff), sludge drying beds, laboratory and pumping station, twin dosing tanks, trickling filters, and a lagoon for further clarification of the filter effluent.

In 1929 a secondary settling tank, designed to serve a population of 45,000 was constructed and placed in operation, replacing the lagoon which had been used as a temporary expedient to secure further clarification of the effluent from the trickling filter unit.

Screen Chamber.—The main interceptor terminates at the plant in a screen chamber where the sewage passes through a coarse bar screen inclined at an angle of 45 degrees, with a spacing of $1^{9}/_{16}$ inches between bars. Following the screen is a proportional weir so shaped as to maintain a reasonably uniform velocity of flow through the screen chamber regardless of the incoming rate of flow, in order to secure sedimentation of gritty material in the pit ahead of and below the screen. Due to the fact that only a small amount of grit was apparent in the sewage at the outset, it was not considered necessary to provide the conventional long grit chamber ahead of the screen. Removal of coarse materials from the screen by hand-raking is practiced. Until the early part of 1936 the screen chamber was not under cover. At that time, under a W. P. A. project, a brick building 20 ft. by 35 ft. was completed over this unit and a grinder installed for shredding the screenings and discharging them into the sewage for settlement in the Primary (Imhoff) tanks. Prior to this, screenings had been disposed of by burial.

In June 1929 a 30-inch by-pass line was installed to permit all incoming sewage to be diverted directly from the interceptor to the primary settling tanks, at such times as it would be necessary to de-water the screen chamber for the removal of grit.

Imhoff Tanks.—Flow of sewage from the screen chamber to the four Imhoff tanks is by gravity. Each tank is 28 by 76 ft. in plan and 32 ft. deep. These tanks are arranged for periodic reversal of the direction of flow in order to secure a more uniform distribution of settled material in the tanks.

Detention period for a 0.75 m.g.d. flow per tank is 2.0 hours. The depth of the sedimentation compartment is 8 ft. 9½ inches and the depth of digestion compartment (bottom of beam to tank bottom) is 16 ft. 6¾ inches.

Pump House.—As originally constructed, this building housed on the main floor a pump room and a section for machine shop and garage. Above the pump room was a room for the laboratory and office. Below the pump room were the wet well, dry well and furnace room.

A contract was awarded in November, 1931, for an addition to the pump house which provided an entrance lobby, stair case to the second floor, a small chemical storeroom, and a larger office. This improvement was completed early in 1932. The major equipment located in the pump house includes:

Three vertical, centrifugal, electrically driven pumps for lifting Imhoff tank effluent to the trickling filters.

Pump ratings approximate 2, 3½ and 5 m.g.d. with motors of 20, 30 and 50 h.p. respectively.

A horizontal air compressor serving the digested sludge air lift.

An electrically driven sump pump for discharging dry well drainage.

A low pressure steam heating boiler.

Sludge Drying Beds.—The twelve beds originally provided are each 25 ft. by 100 ft. providing a total drying area of 30,000 sq. ft., or 0.67 sq. ft. per capita for a population of 45,000.

In May, 1932, a temporary dike was constructed to provide additional sludge drying area east of these beds.

Included in a W. P. A. project late in 1935 was an item for the installation of four drying beds each 25 ft. by 100 ft. and one bed 25 ft. by 177 ft. east of the original beds, thus increasing the total area to 44,425 sq. ft. or about 1.0 sq. ft. per capita. These new beds were placed in service in May, 1936.

Under the filtering medium of sand and gravel are 4-inch tile underdrains on 12.5 ft. centers discharging into a 12-inch main drain.

Dried sludge is forked into horse-drawn dump cars operating on a 24-inch gauge track. Dried sludge not taken directly from the dump cars by users is trucked to a stock pile on the grounds.

Trickling Filters.—This unit was designed on the basis of an anticipated winter tributary population of 48,200, giving a rate of 3,000 population per acre foot, and a summer tributary population of 39,200, giving a rate of 2,500 population per acre foot.

Total filter area is 1.6 acres and the depth is 10 feet. Fixed spray nozzle type of distribution is provided served by twin dosing tanks, air lock type. The filter was constructed as two equal-sized units with the distribution piping and two effluent channels housed in an operating gallery between them.

Specifications as to size of the crushed limestone filtering medium are: Lower 6 in. consisting of stone screened between 2½ and 4¾ in. in diameter and the upper 9½ ft. consisting of stone that will be retained on a screen having circular holes 1 in. in diameter and will pass through a screen having circular holes 2 in. in diameter and no piece to have a single dimension longer than 3 inches.

The following improvements have been made since the original installation:

In April, 1929, a counter was installed on the dosing tank to provide a record of the amount of flow discharged to the filter.

In September, 1929, the orifice size of the spray nozzles was increased from 1 inch to 1 1/8 inches to give an adequate time interval between alternations of the dosing tanks during a 6.75 m.g.d. maximum rate of pumping to them.

Under a contract started in December, 1931, a superstructure was erected over the dosing tanks to eliminate freezing difficulties during winter operation. This was completed in February, 1932. Prior to this it had been necessary to cover the tanks with canvas and planks to overcome such trouble as far as possible.

As the top of the filter walls exposed to sewage spray and frost action had disintegrated to a serious extent, a W. P. A. project was provided in the fall of 1935, for constructing a new concrete coping on the walls. This was completed in June, 1936, and has been maintained in excellent condition by periodic application of a waterproof surfacing material.

Secondary Settling Tank.—As this unit was not included in the original construction program, a lagoon was provided to serve temporarily as a basin for further clarification of the filter effluent.

Construction of the settling tank was begun April 4, 1929, and completed August 28, 1929. The tank has a volume of 150,000 gallons, is 50 ft. square with rounded corners, and provides a detention period of 1.2 hours or a settling rate of slightly over 1,200 gallons per sq. ft. per day for a flow of 3.0 m.g.d. The tank has a total depth of 10 ft. 6 in. at the sides and 12 ft. 1 in. at the center. The water depth is 3 ft. less than these total depths.

A Dorr traction type sludge collecting mechanism is provided. Sludge is withdrawn through a 6-inch pipe extending from the center of the tank bottom to sludge pumps in the adjacent building.

Directional baffles were installed on the inlet side of the tank in November, 1929, to secure a more uniform distribution of the flow through the tank.

Sludge Pump House.—This building was erected and placed in service with the settling tank. It houses two horizontal centrifugal pumps for discharging sludge from the settling tank through a 6-inch line to the Imhoff tanks for digestion, and a horizontal reciprocating pump equipped with electric motor, chain drive, and pressure tank for furnishing, to the plant hosing system, clarified effluent at a maximum pressure of 50 lbs. per sq. in.

A Nash Hytor vacuum priming unit was installed in December 1934 to facilitate priming of the sludge pumps.

Saline Ditch Gauging Station.—Through the co-operation of the United States Geological Survey and the Sanitary District, a W. P. A. project was initiated in the fall of 1935, to provide a concrete weir in the stream and a gauge house and float well. A recording instrument maintains a continuous record of the head on the weir. It was placed in service in June, 1936.

The following summaries show the operation and chemical data for the years 1936–37, and 1937–38. (Average of monthly results shown in report.)

Year May-April	Operating Data					Analytical Data							
	Sewage Flow M.G.D.	Imhoff Tanks Period Hr.	Trickling Filter Rate M.G.A.D.	Lb. B.O.D. Applied per Acre per Day	Final Settling Period Hr.	5-day B.O.D., P.P.M.				Susp. Solids., P.P.M.			
						Raw	Imhoff	Filter	Final	Raw	Imhoff	Filter	Final
1936–37	3.9	—	1.73	1420	1.30	140	97	15	7.3	209	91	48	36
1937–38	3.7	1.55	1.83	2260	1.23	252	148	29	21	211	96	47	27

Comments on Operation

Fiscal Year 1937–8

Consideration will be given in the following section to the activities and experiences of the period from May 1, 1937 to April 30, 1938.

Screen Chamber.—Minor repair of the screenings shredder has been necessary on one occasion during the year. In the fall of 1937 painting of the steel window frames and sash and miscellaneous steel work in the screen house was done.

It has been found necessary to remove grit deposits from the screen chamber at average intervals of three months, in order to avoid the possibility of such material being carried over into the digestion compartments of the Imhoff tanks.

Imhoff Tanks.—With two exceptions, the four tanks have been in continuous service throughout the year. During an eleven-day period in August, 1937, Tank No. 1 was taken out of service to correct a mild foaming condition. In November, 1937 Tank No. 3 was rested for seven days for the same reason.

Gas vent scum was removed to drying beds once during the year, in August, 1937. This represented about 180 cu. yds. of air-dried material.

The direction of flow through the sedimentation compartments was reversed in August, 1937, and March, 1938, in order to avoid excessive accumulations of settled material at either end, and to secure a more uniform distribution of coarse and fine solids in the digestion compartments.

Daily skimming of floating material from the sedimentation compartments has been practiced for the purpose of maintaining a presentable appearance, of reducing odors, and of transferring such material to the digestion compartment where it can be properly decomposed. Agitation

of the floating scum in the gas vents has been of sufficient frequency to insure the ready release of digestion gas and re-settlement of such material for more complete digestion.

The yearly average removals of suspended solids and B.O.D. in this preliminary stage of treatment were 54.5 per cent and 41.3 per cent respectively.

Sludge Drying Beds.—The total quantity of digested sludge handled on the beds during this period was approximately 3,000 cu. yds. as air-dried material. The depth of wet digested sludge drawn on each bed was limited to about ten inches so as to promote quick drying. Use of the beds showed an average of 5½ dryings per bed for the year.

Use of the dried sludge as fertilizer increased considerably through the year especially with respect to its use on agricultural land. During the last four months of this fiscal period it was not necessary to haul any of the dried material to the stock pile, as it was loaded directly from the plant's dump cars into user's trucks.

Eight beds in the south row were re-sanded during September 1937. Sand for this purpose totalled 252 cu. yds. costing $302.40.

Trickling Filter.—With the exception of a 29-hour period on March 16 and 17, 1938, the filter has been in continuous service throughout the year. The distribution lines were given a thorough flushing which improved the surface coverage by the spray nozzles appreciably.

Secondary Settling Tank.—Frequency of pumping of deposited solids from this tank to the Imhoff tanks for digestion has been varied to avoid accumulation of such material in the tank. Seasonal changes in the amount of suspended matter carried to the tank from the trickling filters necessitate such a procedure.

Lagoon.—Use of the lagoon for further clarification of the secondary settling tank effluent, has been limited to the passage through it of only enough flow to maintain an appreciable dissolved oxygen content.

Saline Ditch.—Particular attention has been devoted to restricting any discharge of effluent from the preliminary stage of treatment to the stream only to the infrequent periods of time when the natural flow in the stream is of sufficient volume to provide ample dilution for such partially treated flow.

Laboratory.—The monthly average of chemical analyses recorded in the tables herein are based on a frequency of sampling varying from five to ten twenty-four hour samples per month from each sampling point. During the months of October and November, 1937, and March and April, 1938, increased frequency of sampling was made possible by the part-time employment of a chemist in the laboratory. An extensive program of chemical analyses is desirable not only as a record of the operation of individual treatment plant units, but as a source of information of material benefit for any future design of modifications or additions to the treatment plant.

Grounds.—Use of a section of the grounds by the Recreation Commission was continued.

Grading of the plant roads, setting out of a number of trees, the planting of shrubbery along the south and east boundary fences and the planting

of perennials in the flower garden were among the more extensive improvements.

An outdoor oven was erected in the picnic grove in memory of the late Manager G. H. Radebaugh by members of a club to which he belonged.

The purchase of a 4-acre gasoline driven mower in May, 1937 has aided considerably in maintaining the appearance of the grounds.

Urbana and Champaign Sanitary District,
Per Capita Analysis of Disbursements,
Fiscal Year 1937–38

Based on Population of 43,913.—This basis is used from the standpoint of comparison with the previous year facts.

(1) Cost of Operation (Other Corporate Purposes) per capita....$0.44285

(2) Cost of Operation, Including retirement of bonds, interest, and other corporate purposes but not including principal amount of tax anticipation warrants redeemed.....$1.56496

(Manager's Note)—The cost of operation (other corporate purposes) increased from $0.4071 for the previous year to $0.44285.

The total of all costs per capita (item 2) increased from $1.5260 for the previous year to $1.56496. Contributing factors are:

(*a*) An increase in the total of employee's wages due to increased employment.

(*b*) A change in the policy of paying the annual fee for legal expense. Previous to the fiscal year 1937–38 the attorney's annual fee was not paid until early in the year following the one in which the particular services were rendered. Therefore this cost for the year 1936–37 was paid during 1937–38. The Board of Trustees voted to pay the legal bill for 1937–38 in April, 1938. The voucher was drawn and paid and consequently Account B-1-1 "Legal Expense" includes legal fees for two years of operation.

There are of course fluctuations in each of the expense accounts to be considered in the matter of determining the reason for the upturn in total costs for the year 1937–38.

Based on Population of 42,750.—Inasmuch as the population of the community serviced by this District is fluctuating considerably during any period of twelve months, it is recommended that an estimated population based on round figures, which shall take into account the shifting size of the student body, be used. The above figure was then derived for 1937–38 and applied to the same costs which were previously divided by 43,913.

(1) Cost of operation (Other Corporate Purposes) per capita....$0.45490

(2) Cost of Operation, including retirement of bonds, interest and other corporate purposes, but not including principal amount of tax anticipation warrants redeemed.....$1.60753

Editorial

ANNUAL REPORTS

There is hardly any subject, except B.O.D., that intrigues the interest of sewage works operators more than annual reports. This is probably because of the wide latitude of choice open to the operator in planning his report, but even more because of the conviction of each author or compiler that his type of report is the best, and that his tables, diagrams and text comprise a snappy, accurate, informative report. The annual report gives the author an opportunity for self-expression, and the astute reader can usually gauge the character of the man-in-charge by the scope and style of his report.

Some operators choose to follow the pattern proposed by state health departments, by committees, or by self-constituted authorities, because it is easier to fill out a questionnaire than it is to write a technical, readable paper, but such standardization stifles the urge to be original and the reader feels that here is just another pea from the pod. But the individualist embellishes his report with items not in the written rote of the stereotyped form, and inserts phrases or conceptions outside the humdrum data of daily chores. Imaginative writers tell of annual rivers of sewage, of this depth and that width, flowing from coast to coast, and still less than the torrent of sewage treated during the past year. Others cite the impressive tonnage of solids removed from the sewage as though recounting the tale of Hercules and the Augean stables. Addicts of chlorination, however, put these realists in the shade by boasting of the lethal exploits of the green goddess, who slaughters by the billions those invisible enemies of sanitation, bacteria. Ninety-nine per cent kill is scorned as an admission of unsatisfied demand and incompetency; ninety-nine and nine-tenths is a workaday goal; but ninety-nine and ninety-nine one-hundredths—that is something to talk about.

A man who puts these colorful concepts in his annual report is not one to publish a bare skeleton of tabular data—in fact he may scorn such dull statistics and forget to mention detention periods, monthly analyses, and other details too numerous to mention, but he will dispose of such matters in the lordly German fashion by offering one grand analysis to cover the year's results. Some time ago a prominent English colonel congratulated his colleague for his "Gallic clarity" in avoiding all reference to data in a discussion of experiments on London sewage. Operators who shun tabular data in their annual reports may therefore congratulate themselves on their Continental style.

On the other hand, the unimaginative operator who is enslaved by data may fill his report with folded and refolded tables containing column after column of insignificant items, to which is given the same ponderous attention as is given to the really significant items in plant operation. Weather records in one recent report occupy eight pages, but there are

no analyses whatever of sewage or effluent. Another shows a table of monthly percentage removals, but no parts per million. Another includes enormous blueprinted tables of crowded data, baffling to read even if one were determined to follow through to the bitter end.

Why can't we have reports that are models of conciseness and readability and at the same time sources of all significant data? Probably because no man is able to balance his sense of restraint so nicely against his desire for all-inclusiveness as to result in the ideal or perfect report.

The American annual report on sewage works is unique—there seems to be nothing like it in English, French or German practice. It has been responsible for great progress in the technical control of sewage treatment works, and has convincingly demonstrated that the sewage works operator should keep books just the same as the owner of a business. A little vividness of outlook, however, can help to transform dull columns of figures to an interesting record of accomplishment, and bring attention and acclaim to the author of the report.

F. W. Mohlman

Proceedings of Local Associations

CALIFORNIA SEWAGE WORKS ASSOCIATION

Eleventh Annual Spring Conference

Visalia, California, April 14-15, 1939

MINUTES OF MEETING

Thursday, April 13, 1939

Thursday evening found many groups assembled in the Hotel Johnson lobby renewing old friendships. At 8:00 P.M. approximately sixty members and guests assembled to view a sound film telling the story of Cast Iron Pipe from its inception to its use in modern American cities, presented by U. S. Cast Iron Pipe and Foundry Company.

Friday, April 14, 1939

Business Meeting.—The Eleventh Annual Spring Conference of the California Sewage Works Association convened on Friday, April 14, 1939, at the hour of 9:30 A.M., in the Elk's Hall, Visalia, California, with President Alexander Bell presiding.

President Bell opened the meeting with a short message, saying that this Association was organized, prior to the first conference held in San Bernardino October 9–12, 1928, by a few men who visualized the importance of bringing before the public the necessity for sewage disposal plants, their proper operation and adequate maintenance to promote high sanitary standards for their community, and that by his message hoped to establish in the minds of municipal and state officials the true value of the Association as a technical and advisory board.

A call was then made for Committee reports:

Mr. Wm. Ingram, in the absence of Fred D. Bowlus, Chairman, reported for the Membership Committee, saying that the Committee had corresponded with the City Engineers of all cities having sewage treatment plants, urging that they and/or the plant operator join this Association; and expressed the hope of the Committee that the membership would reach a total of 300 by the Fall Convention.

Mr. John A. Clark, Chairman of the Publicity Committee, exhibited several clippings from local papers saying that two 450 and four 250 word articles appeared in the papers this morning and that others have been prepared to appear in Saturday morning papers of the cities to be visited on the caravan. The assistance of Mr. Robert Van Etten, Educational Assistant of the Alameda County Mosquito Abatement District, in preparing the publicity campaign was acknowledged.

Mr. A. M. Rawn, Chairman of the Legislative Committee, gave a resume of some forty odd bills now before the Legislature appertaining to

sewage disposal and his assurance that the Committee was carefully watching the interests of the Association. Particular reference was made to the Sewer Revenue measure with the prediction that it would become law at this session of the Legislature.

Mr. J. F. Smith, Chairman of Committee on Financing of the JOURNAL, reported that while the advertising space sold for Volume 11, No. 1, of the JOURNAL was a little shy of paying for the cost of publication, an attempt would be made to sell more space in Volume 11, No. 2, and thereby make up the small deficiency.

Mr. A. P. Banta, Chairman of Committee on Certification of and Schools for Operators, reported that preparations for the short course for Operators at the University of Southern California were well under way; that at the present date 108 operators had been certified and that three applications for certification were receiving the attention of the Committee. He stated that fundamentals and laboratory practice will be stressed at the school and that instruction will be under the able direction of Messrs. R. F. Goudey, Carl Wilson, H. O. Banks, Henry C. Meyers, Richard Pomeroy, D. W. Graham, C. F. Tennant, L. J. Alexander and A. M. Rawn.

Mr. Harold May, Chairman of the Committee on Award, stated that his committee was planning a campaign to create more than ordinary interest in the contest for the Award.

Dr. Richard Pomeroy, Chairman Fact Finding Committee, stated that his committee met the preceding evening, organized into groups, and that by the Fall Convention hoped to be able to report definite accomplishments.

Professor Leon B. Reynolds, Chairman on Revision of the Constitution and By-Laws, explained the several proposed changes, giving the reasons therefor, and in conclusion expressed his belief that a copy of the Revisions would reach each member in ample time for study before the Fall Convention.

The Secretary-Treasurer reported that 208 members had paid 1939 dues to date, 61 were delinquent and that 16 new members joined since the first of the year. Though the financial condition of the Association is still good, reserves are gradually being diminished because of the increase in Federation dues and retention of Association dues. Increased printing costs of the JOURNAL are also a factor. The financial statement in brief for the Association is as follows:

Balance as per bank statement	$454.68
Accounts receivable Advertising	250.00
Total assets	$704.68
Outstanding debts	339.12
Balance as of date	$365.56

President Bell asked that all stand for a moment in silence in memory of Mr. Austin Burt, one of our most valued members who suffered a fatal heart attack soon after last Fall's Convention.

Mr. Albert L. Genter of Baltimore, member of the Maryland-Delaware, Water and Sewage Works Association, and Mr. Dario Travaini, City

Engineer of Phoenix, Arizona, member of the Arizona Sewage Works Association, were introduced by President Alexander Bell who extended to them the welcome of C. S. W. A.

Mr. A. D. Wilder, Director of Public Works, City of San Francisco, was introduced by Ben Benas and on recognition he signified his desire to become a member of the Association.

The following members were appointed to serve upon a Resolutions Committee for the Conference: H. F. Gray, Chairman—Leon B. Reynolds.

Technical Meeting.—The business meeting was adjourned at 10:15 A.M. and the technical session opened with the presentation of short papers on the sewage treatment plants at Bakersfield, Delano, Visalia, Wasco and Tehachapi by Messrs. J. Holfelder, Glen Johnson, N. A. Huth, Tipton Mathews and C. S. Chitwood, respectively. The papers were all read by the authors, except that Mr. C. C. Kennedy read Mr. Holfelder's paper and Mr. Ted Gregory read Mr. Tipton Mathews' paper. These papers revealed many interesting design problems, and operation experiences at relatively small sewage disposal plants.

The session was recessed at noon for luncheon which was held in the Elk's Club banquet room. A short address of welcome was given by Mayor J. P. Gannon, to which President Bell replied expressing the appreciation of the Association for the gracious hospitality of the City and its officials. City Manager, J. J. Philippe was introduced and he also offered freely of the facilities of the City. Professor Leon B. Reynolds read a humorous paper said to be the last will and testament of Alexander Bell on his retirement from office next September.

The meeting reconvened at 2:15 P.M. in the Elk's Club lodge room. President Bell announced that during the lunch hour he was informed of the sudden death of Mr. H. M. Ely, a most active member of the Association and member of the Award Committee, and asked that all stand in a moment of silence.

Dr. John P. Russell presented the first paper of the afternoon session on Occupational Health Hazards in Sewage Disposal Plants saying in part that while there were many health hazards in and around a sewage disposal plant their effects may be practically eliminated by reasonable precautions and avoidance of unnecessary exposure.

In reviewing H. J. N. Hodgson's report on "Sewage and Trade Wastes Treatment" Professor Charles Gilman Hyde in 6000 words gave a comprehensive outline of a book of 534 pages creating in many the desire to read the report in its entirety. Though Professor Hyde said no attempt was made to single out California practices, reference was made to several members in attendance and to the practices developed by them.

The third and concluding subject of the session "New Developments in Pipe for Sanitary Sewers" consisted of a group of four papers on Transite, Unglazed Clay, Asbestos Bonded Metal and Amercoat coated concrete pipes presented by J. H. Peterson, H. W. Jewell, L. W. Wyman and E. F. Bent, respectively. Unfortunately, time did not permit discussion of these papers which brought to attention recent developments in pipe for sanitary sewers.

President Bell called for a report of the Resolutions Committee. Mr. Gray read two resolutions, one in appreciation of the hospitality of our host City and the other of condolence to the family of H. M. Ely. The Secretary was directed to spread the resolutions upon the minutes and to send a copy to the City Clerk of Visalia and to the family of Mr. Ely, respectively.

The count of attendance at the above sessions was 95 to 100.

The meeting was adjourned at 5:15 P.M.

Ladies Program.—The ladies spent an enjoyable afternoon and luncheon at Sequoia National Park as guests of the City of Visalia.

Banquet.—The banquet was held in the Elk's Club banquet room with approximately 120 attending. Those seated at the head table were Mayor J. P. Gannon, City Manager J. J. Phillippe, Francis T. Letchfield, the guest speaker, President Alexander Bell and Vice President H. G. Smith.

Mr. Letchfield, Consulting Engineer and Assistant Vice-President Wells Fargo Bank and Union Trust Co., San Francisco, gave an exceptional address.

Saturday, April 15, 1939

Caravan.—Forty-five cars transporting about ninety members and their guests visited the sewage treatment plants at Visalia, Delano, Wasco, Shafter and Bakersfield. All of these plants are new or recently remodeled. The Bakersfield plant was under construction. Each of the plants presented one or more items of interest. At Visalia the old Imhoff tanks were converted into primary digestion tanks. The Delano plant is located in an alkali bed and while a few trees had been planted, gardening is most difficult. The Wasco plant for the most part is housed within a corrugated iron building located in the middle of cultivated fields and has the appearance of a well kept barn. At Shafter the operating parts of the plant are completely enclosed which presents a pleasing appearance. The construction work was well along at Bakersfield and here it was possible to see the procedure in the construction of Hewitt tanks.

The caravan disbanded at Bakersfield at 4:30 P.M.

R. R. RIBAL, *Secretary*

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

Official Bulletin

July 1939

Officers

President, PHIL. J. MARTIN, JR.
1st Vice-President, GEORGE M. BURGETT
2nd Vice-President, MARSHALL N. ROACH
Secretary-Treasurer, F. C. ROBERTS, JR.
Board of Control, JOHN A. CAROLLO
Board of Control, A. L. FRICK, JR.

THE PRESIDENT'S MESSAGE, 1939–40

The year 1939–40 is before the membership of the A. S. & W. W. A., to use as they may. How the fleeting time is used is each individual's concern.

Nothing would be more fitting than for each member to make it his business to contribute in some small way, according to his ability and fancy, to the welfare and success of the Association.

The membership is composed of busy men for the most part, men whose duties make it difficult to give a large part of their time to outside activities. However, it is legend that when there is a task to be done, the busy man is usually called on to do it.

The object of the A. S. & W. W. A. is to bring together those men, professional and non-professional, who may benefit by the exchange of knowledge gained, and information gathered together, on the many phases of sewage disposal, water supply, and water purification. Numbered among the membership are prominent engineers; state, county, and city officials; railroad engineers and executives; private water works owners; and sewage and water works plant supervisors and operators. These men all have problems in common.

The annual and semi-annual meetings are, to me, a great pleasure. In addition I consider the Association with the membership in the past years a source of benefit, due not only to the knowledge gained of the work I am in, but also to the contacts and associations with a fine group of men. I am sure the same thing holds true of every active member.

The membership elected to office May 6th, among others, a Secretary-Treasurer, Mr. F. C. Roberts, Civil Engineer and State Sanitary Engineer. Carlyle, as we all familiarly know him, has been an untiring worker in the organization from its inception. He is deserving of much credit for the present favorable functioning of the organization. In addition to his duties of Secretary-Treasurer, Carlyle has taken on the task of publishing the Association bulletin. Now there is no one man can produce enough material satisfactory to everyone for publication in our bulletin. He needs material from the members in the near and far reaches of the state. Let's throw our feet out and keep material on the way to our Secretary-Treasurer and Editor. Everyone is interested in the activities of the other fellow. Let us have short articles now and then of what is happening around your stamping grounds. Give us articles on operation of sewage disposal plants or water works; problems you have solved that would help some one or be of interest to the membership generally, and it will, I am sure, be welcome.

Last but not least, we must contact old non-active members and new prospects and urge them to join up with the A. S. &. W. W. A. They will benefit much by so doing.

In conclusion I wish to express to the membership my deep appreciation for the honor conferred on me at the May 6th meeting. It will be a pleasure to serve in my humble way.

Cordially,

PHIL. J. MARTIN, JR., *Pres. A. S. & W. W. A.,*
Tucson, Arizona

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Spring Meeting

Albany, New York, June 9-10, 1939

The Spring Meeting of the New York State Sewage Works Association was held in Albany, N. Y., June 9 and 10, 1939, with headquarters at the Hotel TenEyck. One hundred and fifty members and guests including twenty-five ladies were registered.

At the technical session on Friday morning Frank Woodbury Jones, of G. B. Gascoigne and Associates, Cleveland, O., gave an interesting paper in his inimitable style on "Starting a Sewage Treatment Plant." This was followed by a very practical paper on "Sewer Maintenance" by Harold J. Huber, Superintendent of Public Works, Lancaster, N. Y. Both papers provoked considerable helpful discussion.

At the luncheon, Dr. F. E. Coughlin, District State Health Director of the New York State Department of Health, welcomed the group to Albany and expressed the interest of the Health Department in the work of the Association. Following this, Channel Samson was presented with the Rating Committee award in the form of a silver plated loving cup for the excellence of his report on the operation of the sewage treatment plants of Sewer District No. 2, Town of Tonawanda, for the year 1938.

The afternoon session was devoted to two Round Table Discussions conducted successively by Charles C. Agar, Senior Sanitary Engineer, and Ralph C. Sweeney, Albany District Sanitary Engineer of the New York State Department of Health.

The first discussion was on the subject of sludge digestion in Imhoff tanks and in unheated and heated separate digestion tanks. The second discussion covered the topics of odor control, troubles with grit, screenings disintegration and winter operation. These discussions brought out many helpful facts and practices.

The entertainment following the banquet Friday was provided by the three local sections, with A. F. Dappert on behalf of the Parent Body and Dr. Paul B. Brooks, Deputy State Commissioner of Health. Dr. Brooks gave one of his famous Dr. Mortimer Jones skits especially prepared for the occasion on the subject of "A Creamery Waste Nuisance." Mr. Dappert gave a splendid chalk talk on various subjects closely allied to sewage. George Symons on behalf of the Western New York Section set forth various and sundry anecdotes regarding the members of the Association. The Genesee Valley Section presented a unique shadow play with chorus on the vicissitudes of Old Man Stale Sewage. The Long Island Section went to a School for Sewage Works Operators under the baton or old hickory of Professor Hans Morgen VonNichtenblatt.

Through the courtesy of the Albany Chamber of Commerce the ladies on Friday afternoon enjoyed a bus trip to points of scenic and historical interest in the city, including a trip to and lecture on interior decorations at an exclusive household furnishings store. This was followed by a tea at the hotel.

Saturday morning sixty men were on deck promptly for their sunrise breakfast, following which Messrs. R. C. Sweeney and W. R. Schreiner briefly described the various plants to be visited. The motor caravan then proceeded on the inspection trip, visiting the sewage treatment plants of the Albany-Schenectady Road Sewer District, the village of Scotia and the village of Ballston Spa. The group also visited the American Hide and Leather Company's waste screening plant where, although hair is reclaimed in the plant processes, a self-cleaning drum screen removes three tons (dry weight) of fleshings per month from these wastes and thus materially reduces the load on the village trunk sewer and sewage treatment works.

It is planned to hold the next meeting of the Association in Olean, N. Y., October 6 and 7.

A. S. BEDELL, *Secretary*

Reviews and Abstracts

H. W. Streeter

THE ROLE OF MACRO-ORGANISMS IN BACTERIA BEDS

By T. B. Reynoldson

The Surveyor, **95**, 2456 (February 17, 1939). *Sewage Purification* **1**, 2 (February, 1939)

The paper reports investigations on the possible function of Euchytraeid worms, small relatives of the earthworm, in preventing ponding and causing sloughing of the film from the stones of trickling filters. Part of the work consisted of field studies on the Knostrop works at Leeds, part of laboratory experiments. The beds are covered with a growth of the blue green alga Phormidium, which may become thick and sufficiently continuous to cause ponding, and which undergoes an annual spring slough. The worms, Lumbricillus lineatus, are about 5/8 in. long, reddish brown in color and burrow into the algal film as well as the lower film. They are negative to light and more abundant in filter films, where they number 100,000 to 150,000 per cu. ft., than in usual natural environments.

Numbers of the worms varied seasonally in the surface growth. While the quantity of the alga remained high in the winter months, the worms left the surface, but remained most abundant in the upper six inches. They were active at all seasons unless the temperature dropped below 6° C., but only returned into the surface algal growth with a rising spring temperature. Here they became abundant enough to cause the heavy algal blanket to become porous and spongy, whereupon it sloughed off.

Trays containing filter bed stones were placed on the beds in September, 1937. These acquired a healthy growth of Phormidium, but worms were excluded. No sloughing of the alga occurred in the trays, but the growth remained healthy. Finally worms were introduced into some trays in March and within three weeks the algal mat was spongy and eaten away, a clinching proof of the effect of the worms on the beds. It is stated that in summer algal growth tends to keep pace with worm activities.

Laboratory tests on trickling filters 3 in. in diameter and 36 in. long, screened to keep out Psychoda flies, showed that the worms scoured the film in the interior of the filters. The cylinders were operated for 5 and 18 weeks before worms were added. By the fifth week the film (mold, zooglea, etc.) on the stones had become very thick but by the tenth week the filter to which worms had been added was clearing up while the other was gradually choking up; it showed severe ponding in the 14th week. Worms were added to it in the 18th week, and spread to the bottom but in the 21st week they all died in the lower two-thirds of the bed and two subsequent additions also failed to help this filter which finally became too foul to work longer.

Analyses of the effluents of the two beds showed active nitrification in the bed having an active worm population, and its effluent was stable; nitrification was absent in the second filter and its effluent was putrescible.

Discussion brought out that several organisms (Achorutes, various insect larvae) tend to prevent ponding of filter beds. It appears that dosage should be regulated so as to give such biological agents a chance to thrive, and that studies of this nature might reveal the best agents for such work. Some animals might be efficient, but their bodies might pass out and putrify in the final effluent. Optimum conditions for the existence of some single useful animal might be determined, and the beds operated at a permanent high degree of efficiency.

James B. Lackey

THE BIOLOGY OF SEWAGE PURIFICATION

By T. G. Tomlinson

Sewage Purification, **1**, 6 (June, 1939)

The writer introduces the groups of organisms concerned in sewage purification, tells where they are generally found and gives their mode of nutrition in some cases. In general the relation of each group to the various processes of sewage digestion is briefly discussed. Some experimental work is very briefly mentioned, but the results may need confirmation. For example (1) the list of organisms found in the aeration tanks of an activated sludge plant treating milk effluents, when the purification was satisfactory, included Dinobryon ("Dinobryon sp.") which the reviewer has always held to be characteristic of clean streams; and (2) the breakdown in three weeks of a ball of trickling filter film, partly sterilized, was attributed to Psychoda fly larvae. Additional details might have made a stronger presentation of such results.

James B. Lackey

THE DILUTION OF CRUDE SEWAGE

By John Finch

Sewage Purification, **1**, 197–202 (May, 1939)

The beneficial effects of rainwater-diluted sewage on an activated sludge plant are well known. In a certain instance of which the author has knowledge, there is a particular plant of this type which will successfully treat all the sewage from the district served during and for a few days after storm periods whereas, during dry weather, the quantity of sewage which can be treated decreases as does also the quality of the effluent.

Recently there have been attempts in England to take advantage of the above phenomenon by making provision, in the design, to dilute the incoming sewage by the return of a substantial portion of final effluent. At the Mogden Works, a plant treating about 50 m.g.d., provision has been made to return final effluent in amounts up to 50 per cent of the dry-weather flow. For existing plants, the author suggests that return sludge pumps can often be used for effluent return.

At the Aldworke Sewage Disposal Works of the County Borough of Rotherham, the dilution principle has been given a thorough trial. At these works, after primary settling, part of the sewage is treated by a bio-filtration plant and part by a bio-aeration plant, each with its own final settling tanks. During the 6 months trial period a portion of the bio-filtration effluent was fed to the bio-aeration plant influent. Better effluents were obtained than any produced previously and the plant was able to treat a load approximately one-third greater than during the same six months period of the previous year. Careful control of the aeration tank sludge was necessary as in any activated sludge process. However, the sludge produced was never in bad condition during the test period, but was very granular with rapid settling characteristics.

V. G. MacKenzie

CHEESE FACTORY WASTE TREATMENT BY THE GUGGENHEIM PROCESS

By E. F. Eldridge

Bulletin **83**, Michigan Engineering Experiment Station, pp. 9–14 (1939)

Previous studies, reported in Bulletin 77, indicated that the Guggenheim Biochemical Process and several other methods were successful in treating milk wastes. Cheese factory wastes have not responded to usual methods of treatment. This article is a report of the experimental application of the Biochemical Process to cheese factory wastes.

Whey is very difficult and expensive to treat, and due to its high organic content has always been considered as a by-product rather than as a waste. Therefore it was not anticipated that this study would include treatment of the whey. Of course the cheese washings contain a considerable portion of whey and it is the presence of this concentrated material that makes cheese factory waste treatment difficult.

The treatment plant, procedure and results are described and presented. During the early period of operation difficulties occurred due to improper air diffusion which was corrected by first increasing the air capacity at the plant and next by installing woven glass fabric over the perforations in the air diffuser lines. By thus obtaining better air diffusion septic sludge in the aeration tanks was avoided.

The results obtained after overcoming the aeration difficulties are best shown by the tabulated data for the period of August 22 to Sept. 8.

CHEESE FACTORY WASTE TREATMENT

Compiled Data from August 22 to Sept. 8

	Minimum	Maximum	Average
Aeration period, hours	4.5	4.5	4.5
Lime, p.p.m.	230	400	280
Ferric chloride, p.p.m.	25	87	56
pH	6.5	7.5	7.3
Total solids, influent, p.p.m.	1716	5792	2787
Total solids, effluent, p.p.m.	1210	1580	1401
Total solids, removal, per cent	19.5	69.2	45.1
5-Day B.O.D., influent, p.p.m.	1200	3400	2147
5-Day B.O.D., effluent, p.p.m.	100	400	229
5-Day B.O.D. removal, per cent	66.7	96.3	88.5
Settleable solids, aeration tank	50	200	105
Suspended solids, aeration tank	1300	3200	2150
Sludge index	31.3	70.0	50.8
D. O., aeration tank	None	6.0	1.1

The conclusions reached as a result of this study were:

"The Guggenheim biochemical process can be successfully used for the treatment of cheese factory waste. This waste includes the cheese washings, but not much of the whey. The upper limit of the B.O.D. value seems to be about 3,000 p.p.m.

"Conditions must be carefully controlled if good removals are to be obtained. One of the most important factors is the proper diffusion of sufficient air to maintain dissolved oxygen in the aeration tank."

F. E. DEMARTINI

A FILL AND DRAW SEDIMENTATION PLANT FOR TANNERY WASTE

BY E. F. ELDRIDGE

Bulletin **83**, Michigan Engineering Experiment Station, pp. 3–8 (1939).

Results of a study by the Michigan Engineering Experiment Station of a tannery waste treatment plant built by the Armour Leather Co. at Holland, Mich., are reported. The design of the plant was based on experimental studies conducted in 1936 by the Experiment Station, and reported in Bulletin 67.

Reduction in quantity of wastes requiring treatment was accomplished by separation into clean waters and "concentrated wastes." Clean waters are discharged directly to the lake. This separation reduced wastes to be treated from 200,000 to 80,000 g.p.d. The beam house wastes (soaks, washes, water from dehairing machine) are pumped to the treatment plant. The limes are collected and pumped either to the treatment

plant or direct to the sludge drying beds. The tan liquors are collected in storage tanks to equalize their flow throughout the day to the treatment plant. Since the tan liquors are acid they are neutralized and coagulated by the alkaline beam house wastes in a tank equipped with a coagulating mechanism.

From the coagulation tanks the waste flows to four settling tanks filled alternately, each tank holding somewhat less than one day's flow. Supernatant liquid is drawn off by a skimming pipe and sludge is drawn from the bottom of the tanks. To obtain a sludge of lower volume and higher solids content each tank was filled three times before drawing off the sludge.

Detailed tabulations of analyses of composite samples of influent and effluent for each tank are given. A complete cycle of three fillings for each tank is designated as a series. Three of these series were studied by the station. A summary of the total results for all three series is as follows: Total volume of wastes treated, 1,685,200 gals. Sludge volume obtained 33 per cent of this or 556,600 gals. Percentage removals respectively for total solids, suspended solids, oxygen consumed and B.O.D. were 63.0, 95.5, 75.3 and 62.2 per cent.

The efficiency of the plant as a sedimentation unit is exceptionally high; however, operation is made difficult by the large volume of sludge produced. The sludge does not dry well on sand beds nor respond to vacuum filtration. At present sludge is discharged alternately to five beds, each 25 by 300 ft. in area and 2 ft. deep. The partially dried material is removed with wheelbarrows. Studies are still in progress to determine a more satisfactory method of sludge disposal.

F. E. DeMartini

TREATMENT OF RED BEET, TOMATO AND SQUASH WASTE

By E. F. Eldridge

Bulletin **83**, Michigan Engineering Experiment Station, pp. 15–22 (1939)

This is a report of the 1938 study of treatment of cannery wastes by the Michigan Engineering Experiment Station. The 1937 studies, reported in Bulletin 78, established characteristics of the wastes but did not develop methods of treatment. These studies were carried on at the Home Canning Co., Blissfield, and were concerned with treatment of red beet, tomato, and squash waste.

The treatment steps were: (1) screening through a North rotary screen covered with 28-mesh screen; (2) addition of lime and ferric chloride in a mixing trough receiving the constant flow of wastes from an orifice box; (3) coagulation in a tank with slowly revolving paddles; (4) sedimentation either on a fill and draw or flow through basis.

Results: (*a*) *Red Beet Waste.*—Average volume of wastes per ton of beets 1,260 gals. With this waste the flow through the sedimentation tank produced a much denser sludge than that obtained with fill-and-draw sedimentation (1.85 per cent solids against 1.3 per cent). Sludge volume was 30 per cent of waste for fill-and-draw and 18 per cent for the continuous process. Ferric chloride was found to be unnecessary since no advantage was obtained when it was used with lime. Screening effected a removal of 56 per cent of the suspended material and coagulation 90 per cent of that remaining. Final B.O.D. values of 1,500 to 2,500 p.p.m. may be expected. The chemical treatment resulted in a removal of 43.3 per cent of the B.O.D. in the screened waste. About 9 lb. of lime per 1,000 gals., followed by a 2.5 hour settling period, was most effective. Sludge was dried on an underdrained sand bed. The sludge was dosed to a depth of 7 in. and was sufficiently dry to remove in 4 days. The final cake was 1 to 1.5 in. thick. A much deeper application would have been practical.

(*b*) *Tomato Waste.*—The average volume of waste per ton of tomatoes was 360 gals. No ferric chloride was used. Lime dosage was 800 to 900 p.p.m. with the fill-and-draw process and about 1,000 p.p.m. with the continuous process. The latter procedure gave a denser sludge (1.4 per cent solids compared to 0.88 per cent). Sludge volume was 22.5 per cent of waste for fill-and-draw and 13.4 per cent for the continuous process. Sludge was dried on the sand beds with 10 in. depth at dosing. It was dry and ready to remove in 5 days. The screen removed 79.7 per cent of the suspended solids and

chemical treatment 86.5 per cent of that remaining. The B.O.D. of the final effluent was about 1,000 p.p.m. and suspended solids 20 to 52 p.p.m. depending upon details of treatment. Chemical treatment removed 39.0 per cent of the B.O.D. in the screened tomato waste.

(*c*) *Squash Wastes.*—Squash wastes did not respond to this treatment due to clogging of the screen, formation of light clumps on coagulation which tended to float, and general difficulties in the treatment. In squash canning a concentrated waste is produced during one step (skinning and removal of seeds and pulp). The quantity of this waste was 10,800 g.p.d., about 20 per cent of the total waste; it contained 2.44 per cent solids of which 12,000 p.p.m. was suspended matter. This waste was separated and dried directly on the sand beds, thus reducing the suspended solids of the general factory wastes by 88.4 per cent. The latter waste should be screened only. No estimate of B.O.D. reduction was possible due to the difficulty of making a B.O.D. test on the concentrated waste.

F. E. DeMartini

REPORT OF THE SPECIAL COMMISSION INVESTIGATING SYSTEMS OF SEWERAGE AND SEWAGE DISPOSAL IN THE NORTH AND SOUTH METROPOLITAN SEWERAGE DISTRICTS AND THE CITY OF BOSTON

Massachusetts House No. 2465, Dated June 15, 1939. Pages, 179, with figures.

This is a report of a special commission of twelve, composed of two senators, five representatives, State Commissioner of Public Health, Commissioner of Metropolitan District Commission, director of sewerage division of the same, director of sanitary engineering of the State Department of Public Health, and the sewer engineer of the City of Boston, accompanied by a report of the consulting engineers, Greeley and Hansen, and Metcalf and Eddy. The commission undertook to determine the extent of pollution by sewage in Boston Harbor and the need of sewage treatment, the adequacy of the present North and South Metropolitan Systems, and the Boston Main Drainage, the cost of necessary improvements, and the public sentiment as to the necessity of treatment. The commission resulted from the findings of engineers in a report, House No. 1600, of 1937 (*This Journal*, **9**, 709 (1937).

Public hearings developed a demand for correction of existing pollution in the Harbor, which now receives over 250 million gallons of raw sewage every day. Yachtsmen complained of the sleek areas. Bathers complained of the grease balls and the closing of polluted bathing areas.

The studies made were based on the findings in House No. 1600, of 1937, from which the commission concluded that a potential menace exists "to public health and a serious handicap to recreational expansion of Boston Harbor"; pollution discharged is a decided threat to property values; conditions in Boston Harbor are serious; and the potential dangers to health will tend to increase.

The consulting engineers studied the pollution of the Charles River, the Mystic River and tributaries, with methods of correction, and the proposed treatment of the sewage of North and South Metropolitan Sewerage Districts, as well as the Boston Main Drainage. The economics of the recovery of fertilizer from sewage sludge were also considered.

For the improvement of conditions in the inland tributaries, the commission accepts the recommendations of its engineers for a construction program involving the expenditure for the relief and overflow sewers of $14,695,000, and for three sewage treatment works (for partial purification at the three main outlets) $10,022,000, a total of $24,717,000.

On the sludge problem, the commission recommends barging to sea, since the sludge would be of too low a fertilizing value to justify its preparation therefor.

In general, there are eight principal streams tributary to Boston Harbor, all of which are polluted. Within their drainage areas are 53 municipalities, of which 33 are included in the North and South Metropolitan or Boston Main Drainage Districts.

These three sewerage systems serve about 200,000 acres and over 2,000,000 people, with about 300,000,000 gallons of sewage per day. Future population estimates indicate about 2,170,000 persons in 1955.

Faced with the problems of pollution in the various river valleys, the commission considered three possible remedies:

(1) Treatment of sewage at overflows by local authorities.
(2) Separation of storm water from sewage.
(3) Construction of storm overflow conduits to intercept the discharge from trunk sewers.

The first was dismissed as impractical; the second, as too expensive. Only the third was believed practical and is recommended with a relief sewer program.

The commission believes the correction of the pollution of Boston Harbor is an immediate necessity, by works giving treatment in partial form, to remove floating solids and grease, and reduce the suspended solids and bacterial pollution, with disposal of sludge by barging to sea. The details of the sewage treatment estimates are summarized in Table I. The proposed method of treatment comprises fine racks, grit chambers, aero-chlorinating tanks, sedimentation tanks, sludge storage tanks, and equipment for disposal of sludge at sea, and chlorination equipment for disinfection during the recreational season.

TABLE I.—*Estimated Cost of Sewage Treatment Works for Removal of Pollution from Boston Harbor*

Works	North Metropolitan	South Metropolitan	Boston Main Drainage
Capacity, m.g.d.	125	112.5	85
Population Served, as of 1955	750,000	900,000	400,000
Construction Cost:			
Total	$3,784,000	$3,058,000	$3,180,000
Per m.g.d.	30,300	27,200	37,400
Per capita	5.05	3.40	7.95
Operating Cost:			
Total	$284,000	$249,000	$240,000
Per m.g.	6.84	7.34	7.74
Per capita	0.40	0.33	0.60

Financing is recommended with 40-year bonds, with service on the basis of assessed valuation for the present, with temporary relief for the transient population problem by providing for the disposal of sludge from the Boston Main Drainage Works at no cost to Boston other than its share of the Metropolitan sewerage assessments. One member of the commission, the sewer engineer of Boston, recommended postponement of construction other than the sewage treatment works, because of the financial problems of Boston.

The report of the consulting engineers takes up the detals of the situation, both from the sewerage as well as the treatment standpoint.

The extent of the sewerage systems may be summarized:

System	Ultimate Area Acres	Per Cent of Ultimate Sewered in 1935
Boston Main Drainage	12,800	
North Metropolitan	71,300	36.8
South Metropolitan	140,000	22.0

There are many industries of various kinds, including tanneries, woolen mills, paper mills, glue and gelatine works, rubber works, and oil refineries.

The area tributary to Boston Harbor comprises 645 square miles, of which 350 square miles are within the area ultimately tributary to the three main outlets.

The area of the harbor at high tide is 27,700 acres, and at low tide, 25,300 acres. The rise and fall of the tide varies from 6 to 15 feet.

The minimum land runoff to the harbor is believed to be about 129 m.g.d. During mean tides, about 76,086 m.g. enter and leave the harbor, or about 150,000 m.g.d. The temperature of the harbor water ranges from 28.8 to 71.6 deg. F.

The existing works were described in House No. 1600.

The treatment works are planned for 1955, and sewers for 1975. For population data, the 1935 Massachusetts census was available. Summarized, the figures are:

Sewerage District	Population in 1935			Population in 1955		
	Resident	Contributing		Resident	Contributing	
		Total	Per Cent		Total	Per Cent
North Metro...	740,585	696,470	94	790,000	750,000	95
South Metro...	844,318	643,690	76	980,000	900,000	92
Boston Main...	415,524	415,524	100	400,000	400,000	100
Total.....	2,000,427	1,755,684	88	2,170,000	2,050,000	95

In the North Metropolitan, eight municipalities have decreased in population since the years of their highest population. The transient population of Central Boston was estimated from a count on June 28, 1927, between 7 A.M. and midnight of 1,656,953 persons, or round trips of some 825,000 persons.

The river pollution problems are discussed, with the recurring problem of cost of separation. Parts of Boston and Brookline have separate sewers. Storm overflow conduits are recommended.

The water consumption varies from 43 to 106 gal. per cap. daily in the North Metropolitan area. The maximum ground water rate was estimated at 2,577 g.a.d., but a figure of 3,000 g.a.d. was used. An allowance of 13,000 g.a.d. was made for industrial flows in areas now zoned for industry.

Capacities were recommended varying from 10 to 15 times the domestic flow, plus the maximum of flow of ground water and industrial wastes, on upland conduits, whereas on conduits tributary to channels discharging directly to tidewater, three times the domestic flow was used. Leakage of salt water should be prevented.

The pollution of Boston Harbor is discussed at length. The load in 1935 was:

System	Contributing Population	Average Flow of Sewage, M.G.D.
Boston Main Drainage.....	493,000	75.3
North Metropolitan.....	696,470	82.9
South Metropolitan.....	643,690	86.5
Total.....	1,833,160	244.7

The harbor is used by 21 yacht clubs, with 1,370 boats (other boats bringing the total use to 3,500 boats). Twenty-nine bathing beaches are used by as many as 100,000 people on pleasant Sundays and 1,500 on week days, or a total during the season of 5,300,000. In the year 1937, some 7,900 vessels went in and out of the harbor. A total of 8,180,452 persons traveled on the waters, or a daily average of 22,400.

There are several shellfish areas in the harbor still open.

After discussing the standards for bacterial quality of bathing beaches, the engineers conclude that a single *B. Coli* index of 1,000 per c.c. is a warning of excessive contamination, and an average index in excess of 3,000 *B. Coli* per 100 c.c. indicates danger to the public health.

The sewage field at times may extend as far as the sleek field. Both cover large portions of Boston Harbor. The shore waters in some places have a higher content of bacteria than is safe for bathing. Enough stranding of grease balls occurs to injure bathing beaches. The shellfish industry should be maintained and conditions improved.

The character of the sewage is discussed, as typical of a relatively strong domestic sewage. The suspended solids and fats are not high. The chlorine demand on the North Metropolitan appears high.

SUMMARY OF ANALYSES

System	Year	Parts per Million				Susp. Solids Lb. per Cap. per 24 Hr.
		Susp. Solids	5-Day B.O.D.	Chlorides	Fats	
Boston Main...	1935	162	157	4,080	50	*0.19
	1936	119	144	3,478	34	
North Metro...	1935	256	249	3,280	83	*0.20
	1936	152	175	3,151	41	
South Metro...	1936	156	119	198	49	0.17

* Average for 1935–1936.

The details of the proposed treatment are discussed. The preliminary racks are proposed with 3/4 in. opening; aerochlorinating tanks with 3 or 4 min. contact, using 0.02 cu. ft. air per gal. sewage, and chlorine 2 to 3 p.p.m.; sedimentation for one hour, or 20 minutes for three times the dry flow; chlorination to apply 15 to 20 p.p.m. for 150 per cent of average dry flow; sludge storage capacity for 7 days. Space and head are to be left for suitable mixing and flocculating tanks; for mechanical filtration of settled effluent. Complete treatment was considered unnecessary.

For sludge dewatering, the centrifuge was deemed experimental. Preparation of sludge for use as fertilizer was not considered warranted. One sludge boat was recommended for each of the three projects.

Financing is discussed, with proposed legislation.

The report is an excellent summary of the problem and the remedies for pollution in a large metropolitan area, including a much-used harbor.

LANGDON PEARSE

ARTIFICIAL LAKE FOR THE PURIFICATION OF RIVER WATER AT GLAUCHAU, SAXONY

BY GEORG WEICKER

Sewage Purification, 1, 29–31 (January, 1939)

At Glauchau, Germany, the pollution of the Zwickauer Mulde with domestic sewage and trade wastes has caused serious difficulty at the large textile finishing works which use the stream as a source of industrial water supply. Even with coagulation and filtration, it was impossible to produce a satisfactory water when the Mulde was particularly badly polluted.

In order to effect a partial purification of the raw water by sedimentation and biological action, there has been constructed a lake through which the diverted river water is passed before going to the filtration plant. The lake serves not only as a purification

unit but also for storage, making it possible to draw only the better quality river water. By cooperation of factories upstream with regard to time of waste discharge, former difficulties from contamination of the water with sulfite liquors have been largely eliminated.

The lake has a net usable capacity of 143 m.g. and covers an area of approximately 99 acres, the large surface area being provided for self-purification purposes. At the time of construction, the industrial water usage amounted to about 1.1 m.g.d. and it is estimated that 3.3 m.g.d. may be required in the future.

To form the lake, which is roughly triangular in shape, it was necessary only to construct an enclosing bank along one side, the remainder of the enclosure being formed by a natural slope and the river levee. The enclosing bank was formed of sand and gravel, covered with a layer of loam and protected on the water side with a gravel facing. Some trouble with wave erosion was encountered and it was later found necessary to pave a portion of the slope on the lake side. The lake bottom was left in its original condition except for the limited areas from which bank-forming material was excavated. Considerable leakage has occurred through these areas where the underlying gravel was exposed by removal of the top soil, although much sealing action quickly took place on these areas where they were located in the zone of heavy sludge deposition.

The lake is a scene of biological activity and many small fish, frogs, and water fowl are present. The lake was first filled in October, 1937, and by January the water had reached a quality satisfactory as a source of supply for the purification plant serving the industries.

V. G. MacKenzie

THE SEWAGE DISPOSAL SYSTEM OF CAIRO

By C. Hammerton

Chief Chemist, Main Drainage Department, Ministry of Public Works, Egypt

The Surveyor, **95**, 619–20 (May 12, 1939)

The paper deals with the original sewage collection works of Cairo, Egypt; the corrosion of the main collector by hydrogen sulfide; methods of repair, and procedure in the construction of a new collector.

In 1885 a commission recommended that the eight km. of ancient storm water drains be extended; that the three existing outfalls be connected to new collectors to irrigate nearby uncultivated land; and that all sanitary sewage be excluded. In 1906 Mr. Carkeet Jones was appointed to prepare plans for the city drainage where sanitary conditions had become very undesirable. The works he designed were for a future population of 960,000 (by 1932), and were based on a per capita sewage flow of 50 liters per day. Of the area served 1,331 hectares are drained by gravity and 1,772 hectares by means of 63 ejector stations to which compressed air is delivered through cast iron mains from a central station. The main collector is a circular sewer 1.6 m. in diameter and 13.6 km. long to the pumping station. Here sewage passes through a bar screen with 1.6 cm. spacing between bars, and is then pumped 11.6 km. through a 91.5 cm. diameter cast-iron rising main to the treatment works. These comprise six hydrolytic tanks with effluent weirs so divided that 20 per cent of the flow is carried into the liquefying chambers. The effluent from the liquefying chambers flows through graded gravel filters 1.95 meters in depth, being fed from traveling distributors worked by wire ropes driven by electric motors. Dosing rate is 0.9 cu. m. (195 gal.) per cu. m. per day. The filter effluent is mixed with the settled effluent and disposed of to the sewage farm which is in sandy soil.

Due to complaints of sewage odors, manholes and ventilating shafts on the collector were soon covered. In 1918 an examination of the interior revealed serious corrosion of the concrete, and silt accumulation varying from 30 to 60 cm. in depth for the entire length of the collector, resulting in great loss of carrying capacity. To overcome the corrosion: ventilation, continuous removal of deposited solids, chemical treatment of the sewage (with ferrous sulfate and lime), and entire exclusion of air from the collec-

tor were tried, about 1921. Chlorination was considered but was found to be too expensive to be practical. Materials were also tested for resistance to corrosion under actual conditions inside the collector. Portland blue pressed vitrefied bricks were found to be quite immune, and Ciment Fondu also quite resistant. In 1923 attempts to reconstruct the arch of the collector and to enlarge the internal area were defeated due to excessive loading of the system and necessity of diverting or stopping the sewage flow to accomplish these repairs. Therefore construction of a second collector and rising main was deemed advisable. This work was started in 1925 and the new collector was put into operation in 1929.

The second collector is horseshoe shaped, 1.9 m. by 1.8 m. internally and 5.1 km. in length. It is built of cement concrete and lined with blue pressed, highly vitrified bricks set in 1 to 1 cement mortar; a space was left in the face of the joints which was then filled with a mixture of tar and pitch. The manholes are similarly built, the ironwork being encased in a lead jacket.

Upon completion of this new collector the old one was examined, and in some sections the concrete of the arch was penetrated to a depth of 14 cm., while just above the water level the concrete had been eaten away to a depth of 18 cm. in places. This collector has been repaired in part with Ciment Fondu, which had been found to be better than other cements for the conditions. This work was completed in 1937 and the collector has not been in use long enough to report upon the behaviour of the Ciment Fondu. In the new collector the vitrified brick lining has been immune from attack but the tar and pitch jointing has not been ideal. The silt problem still remains. Eight catchpits were constructed in suitable places and these are cleaned out daily. About 18.5 cu. m. of silt are removed from the old collector and 19.0 cu. m. from the new one, each day.

Discussion, **95**, 853–55 (June 30, 1939).—Mr. L. F. Mountfort (Edmonton) introduced the paper in the absence of Mr. Hammerton, and pointed out these unusual conditions: (1) Dry weather flow in 1906—9 gal. per capita per day, and in 1927—11 gal. per capita per day, (2) the large quantity of silt in the sewage, 2 cu. yds. per m.g., (3) the extremely low rainfall (about 1 inch per annum), (4) sewage temperature 19° to 30° C. All these factors helped to produce the septic conditions in the collector and the destruction of the concrete. The sewage farm covers 3,150 acres and citrus fruits and date palms are raised at a net profit. Sludge is dosed 4 in. deep on sand beds and dried in 3 to 6 days. There is a big demand for the dried sludge. Storage of the dried sludge for two to three months was advised by the public health authorities to prevent spreading of parasitic diseases through its use. Mr. Mountfort stated that the recently installed treatment plant included a Dorr fixed-cover digestion tank and three experimental activated sludge units on the Simplex, Sheffield, and air diffusion systems respectively.

Mr. Godfrey Taylor (Westminster) discussed the question of laying the new collector. Since it was to be laid in water-logged ground the authorities hoped to put a waterproofing outside the whole of the concrete. Since this was practically impossible, Mr. Taylor suggested that it was much more important to ensure proper mixing and grading of the concrete to render it non-porous as his experience in Alexandria, Egypt, indicated that dense, non-porous concrete was only slightly affected by H_2S corrosion. Mr. Taylor suggested that sand be stopped from entering the collector to overcome the silt problem. He was told this was practically impossible since the Egyptian has used sand to clean his cooking utensils for the past 3,000 years. At present 75 men are permanently employed on the new collector and 102 on the old, to remove sand from the catch-basins which have been installed.

Mr. J. B. Harvey (Rochester) reported similar difficulties with concrete corrosion at Rainham, Kent. In his opinion the principal point was the sedimentation of the detritus in the collector, which entrained sufficient organic matter to result in septic conditions. He believed that the recommendation to eliminate the detritus was the proper step to have taken. He also was of the opinion that in using Ciment Fondu, an acid resisting cement, the best material for the purpose had been selected.

Mr. T. W. Lockett (West Middlesex) and Mr. A. H. Holroyd (Dagenham) discussed the need for more information on the nature of concrete disintegration. It was men-

tioned that the principal factor was whether the cement contained any free lime. Portland cement was said to contain up to 5 per cent free lime, which would react with the sulfates to give calcium sulfate. Certain hydrated calcium aluminates, present in Portland Cement, were also said to react with sulfates to give a calcium sulfo-aluminate. Both reactions lead to expansion and disintegration of the concrete.

Mr. H. H. Stanbridge (Epsom) reported concrete disintegration difficulties due to presence of magnesium and calcium sulfates, either as crystals or in solution in ground water. They are using aluminous cement for all underground concrete work likely to be affected.

In reply to these and other comments brought out in the discussion, Mr. Mountfort responded that he was in agreement that the silt was the main cause of the trouble, but that its elimination was apparently a very difficult matter. In regard to compactness of the concrete he stated that the concrete used on the old collector was a 5 : 3 : 1 mixture which would not produce a very compact concrete, and he thought a richer mixture would have been beneficial.

F. E. DeMartini

SEWAGE PURIFICATION IN THE PARISIAN AREA. CONSTRUCTION OF A BIOLOGICAL SEWAGE TREATMENT WORKS AT ACHERES

By F. Pouquet

Travaux, **79**, 87–95 (March, 1939)

From the strides made since 1927, the City of Paris and various adjoining departments decided to adopt a joint program for handling the sewage of the Parisian area. As a result a comprehensive network of intercepting sewers is under construction which will terminate in the agricultural area of Acheres.

At present the sewage of Paris is spread on farms in four different regions which receive an average of 500,000 cubic meters (132 million gal.) per 24 hours. However the volume of sewage is increasing, and may some day reach 2,400,000 cu. m. (634 million gal.) per 24 hours.

Although sewage irrigation has proven satisfactory, additional area cannot be found for farming. Hence biological treatment at a central point is to be used for all flows over 500,000 cu. m. per 24 hours. This conclusion was reached after many years of experiment.

The first unit is now under construction with a capacity of 200,000 cu. m. per 24 hours, comprising primary settling tanks, activated sludge treatment, secondary settling, digestion of the excess sludge and disposal of the wet sludge on farm areas.

The four primary settling tanks are 35 metres (115 ft.) diam. and 3.5 metres (11.5 ft.) deep at the outside, of the circular type, totaling 12,500 cu. m. capacity, giving a 1½ hour settling period. Sludge and scum mechanisms of the Dorr type are provided.

The twelve aeration channels are 200 metres (656 ft.) long, 7 metres (22.96 ft.) wide and have a maximum depth of 3.5 metres (11.5 ft.). The total capacity is 50,000 cu. m. equal to a period of 6 hours for a flow of 200,000 cu. m. per day. The mixed liquor is aerated by blowing air through vertical pipes with an outlet 2.75 metres (9 ft.) below the water surface spaced 1 metre (3.28 ft.) apart.

Four secondary settling tanks, similar to the primary tanks, but lacking scum cleaners, have a capacity of 12,500 cu. m. and a detention period of 1½ hours. The returned sludge is estimated at 35 per cent of the incoming sewage, and will be handled by four air lifts capable of handling 100,000 cu. m. per 24 hours.

At the time of flood the effluent is pumped to the Seine.

Six digestion tanks are provided with a total of 18,000 cu. m.; of these four are 21 metres (69 ft.) diam. and 12.5 metres (41 ft.) deep, with flat bottom, kept at 25 to 30 deg. C. by revolving pipes carrying hot water. Another is 20 metres (65.6 ft.) diam. and 17 metres (55.8 ft.) deep, with conical bottom, in which sludge is intermittently circulated with a helical pump set in the tank and heated by coils of pipe. Another is 18 metres (59 ft.) diam. and 20 metres (65.6 ft.) deep, with a conical roof, in which

sludge is circulated by a centrifugal pump set outside and heated by introducing water at 80 deg. C. Two gasometers, each holding 1,600 cu. m., are provided.

From tests sludge is expected with 95 per cent moisture. A maximum fermentation is expected at 25 to 30 deg. C. with a recovery of 20 to 30 liters of gas per capita.

The air compressors are operated either by electric motors or gas engines to develop a pressure around 3 metres of water (4 lb. per sq. in.). The gas engines have either six or eight cylinders. The cooling water will be used to heat the digestion tanks.

The digested sludge will be distributed over the fields around the works.

The works should be in operation by the end of 1939.

Most of the equipment is supplied by the Dorr Company.

LANGDON PEARSE

BREWERY WASTES

THE INFLUENCE OF BREWERY WASTES ON THE SEWAGE OF MUNICH

BY EUSTACHIUS STECHER,

Director of Public Works, Munich

Gesundheits Ing., **62**, 394 (July 15, 1939)

There are nine large breweries, and several smaller ones, in Munich. The wastes from the breweries are discharged into the city sewers and treated at the Munich sewage treatment works.

A survey of wastes from four breweries was made from June to November, 1938, by the chemist of the sewage works, G. Rupprecht. About 80 samples were analyzed. The average results are shown in Table I, compared with average results of analyses of the sewage, containing the brewery wastes, received at the treatment works.

TABLE I

	Temp. Deg. C.	pH	5-day B.O.D. P.P.M.	Oxygen Consumed P.P.M.	Susp. Solids P.P.M.		Settleable Solids C.c. per L.
					Total	Volatile	
Brewery Waste	24.6	7.3	611	85	304	254	4.56
Sewage	12.9	7.4	162	33	160	115	2.82

All breweries in Munich use 7 million cu. m. of water per year (1.85 billion gallons per year, 5.07 m.g.d.). The production of beer in 1937 was 211,000 cu. m. (55.76 million gallons, or 1,800,000 barrels, per year). The ratio of wastes to beer produced was therefore 1 to 33. This is higher than has usually been reported.

The samples of wastes were collected from 8 A.M. to 5 P.M. The discharge at night is relatively clean water, amounting to approximately 1.0 million cu. m. per year, leaving 6.0 million cu. m. (1,585 billion gallons) per year, or 4.34 m.g.d., as the average volume which corresponds with the analyses given in Table I.

The total sewage flow, including wastes, treated in 1937 was 104.7 million cu. m., or an average per 24 hours of 287,000 cu. m. (75.8 million gallons). The population was 703,000. The dry weather flow was 96.2 million cu. m. per year. It is estimated that approximately 3.0 million cu. m. per year of sewage is discharged untreated to the river, in the stormwater.

The temperature of brewery wastes averaged 24.6° C., of sewage 12.9° C. The relation between the chemical constituents of the brewery wastes and the total sewage flow was as shown in Table II.

The B.O.D. of the brewery wastes is thus seen to be a greater percentage of the sewage B.O.D. than any similar comparison of other constituents. The B.O.D. of 611 p.p.m., when corrected for the night flow of 1.0 billion cu. m. per year, reduces to 524

TABLE II.—*Percentage Brewery Wastes are of Total Sewage*

Settleable Solids	Suspended Solids		Oxygen Consumed		5-day B.O.D.
	Total	Volatile	Unfiltered	Filtered	
9.3	10.9	12.7	14.9	13.5	21.6

p.p.m. for the average 24-hour flow of 5.07 m.g.d. A further correction for the dissolved oxygen in the night flow reduces this only 1.2 p.p.m., a negligible amount.

The "population equivalent" of the total sewage, including wastes, averaged 66.1 gm. (0.145 lb.) per capita per day. (*Note by Abstractor:* This is somewhat less than the American factor of 0.167 lb. per capita per day, for large cities.) The Munich sewage flow is 108 gal. per cap. per day. The sewage alone averaged 51.8 gm. (0.114 lb.) per capita per day. Brewery wastes therefore amounted to 0.0315 lb. per capita per day, or 22,140 lb. per day for the population of 703,000.

According to Imhoff the daily per capita B.O.D. for German cities is 54 gm. (0.119 lb.). This value would give a population equivalent of 186,000 for the brewery wastes. These wastes are therefore an important factor in the problem of disposal of the Munich sewage.

Note by Abstractor.—In order to compare with American factors, the Munich results have been computed below to show the constituents of the wastes per barrel of beer:

WASTES FROM MUNICH BREWERIES

Average 4,930 Barrels of Beer per Day

Constituent	Per Barrel of Beer (31 Gallons)
Volume	1,030 gal.
5-day B.O.D.	4.50 lb.
Susp. Solids, Total	2.23 lb.
Susp. Solids, Volatile	1.36 lb.

BREWERY WASTES

BY F. W. MOHLMAN

Modern Brewer, **21**, 35 (Jan., 1939)

Wastes from 28 breweries in Chicago were gaged, sampled and analyzed by The Sanitary District of Chicago in 1937. Weirs were built in all outfalls, and flows were recorded on a gage. Samples were collected every 15 minutes and composites were made in proportion to the flow for the day sample, from 7 A.M. to 6:45 P.M., and a night sample, from 7 P.M. to 6:45 A.M. These samples were analyzed and the results of analyses, plus records of flow, were used to compute the pounds of various constituents discharged to the sewers. The results were further correlated with the number of barrels of beer brewed during the period of sampling.

Typical results of analyses are shown in Table I, as compared with average results of analyses of sewage from the North Side Treatment Works of The Sanitary District of Chicago.

The dewatering by squeezing of spent grains produces a very concentrated waste, but the volume is quite low. Washing of barrels produces a much more dilute waste, but of large volume. The total waste has a high B.O.D., is comparatively low in nitrogen, is slightly acid, and contains 500 p.p.m. volatile suspended solids out of a total content of 650 p.p.m.

The total flow of wastes per 24 hours from the 28 breweries was 3.5 million gallons per 24 hours; the total constituents per 24 hours were: 5-day B.O.D., 35,000 lb., suspended solids, 18,800 lb.; and volatile suspended solids, 14,300 lb. At the accepted

TABLE I.—*Analyses of Brewery Wastes*
Results in Parts per Million

Source	5-day B.O.D.	Suspended Solids		Total Nitrogen	pH
		Total	Volatile		
Total Outfall	1,200	650	500	50	6.1
Grain Squeezer	5,700	8,550	8,300	860	4.1
Barrel Wash	950	250	170	12	5.7
Sewage, No. Side T.W.	107	140	93	17	7.2

value for B.O.D. of 0.167 lb. per capita, the "population equivalent" of the wastes is 210,000.

The production of beer averaged 400 barrels per brewery per 24 hours, varying from 120 to 1280. The flow and constituents per barrel were as shown in Table II.

TABLE II.—*Flow and Losses per Barrel of Beer*

Constituent	Per Barrel of Beer (31 Gallons)
Volume	320 gal.
5-day B.O.D.	3.1 lb.
Susp. Solids, Total	1.68 lb.
Susp. Solids, Volatile	1.28 lb.
Total Nitrogen	0.134 lb.

The flow varied from 180 gal. per barrel in winter to 500 gal. per barrel in summer.

The recovery of spent grain involves dewatering by means of an Anderson expeller, or similar device, which results in the discharge of a very concentrated, milky liquid, analyses of which are shown in Table I. In several cases, special tests were made to show the effect of this waste, as compared with the total discharge from the brewery. The flow was only 7.5 per cent of the total, but suspended solids amounted to 31 per cent, and 5-day B.O.D., 37 per cent. The losses of suspended solids and B.O.D. were a substantial proportion of total plant losses, although the total volume was quite low. It would seem possible to improve the dewatering procedure by use of more efficient types of presses or filters.

Brewery wastes influence the cost of treatment by adding to the volume to be pumped, by increasing the cost of disposal of solids, and by requiring more air in the activated sludge process. It is probably less expensive, however, to treat such wastes with sewage at the sewage treatment works than at the brewery.

Note by Abstractor.—In *This Journal* for March, 1939, page 298, R. J. Bushee gives the unit factors for wastes from a brewery at Houston, Texas. The following table shows these factors, compared with the Chicago results reported by Mohlman and the Munich results reported by Stecher:

Place	Population	No. Breweries	Total Wastes, M.G.D.	Total Pop. Equiv. at 0.167 Lb. per Cap./Day	Flow and Constituents of Wastes			
					Flow, Gal. per Bbl.	Susp. Sol., Lb. per Bbl.	5-day B.O.D., Lb. per Bbl.	Pop. Equiv. per Bbl. at 0.167 Lb.
Houston	—	1	0.48	21,000	350	1.1	2.4	14
San. Dist. Chicago	4,587,000	28	3.50	210,000	320	1.68	3.1	19
Munich	703,000	9+	4.34	133,000	1,030	2.23	4.50	27

A NATIONAL SURVEY OF THE BREWING INDUSTRY

For the Year Ending Dec. 31, 1938
Research Company of America
United States Brewers' Association

21 East 40th St., New York, N. Y.

This report deals mostly with an analysis of the 1938 beer production and withdrawals. It gives a list of all breweries in the United States, listed by states, and shows the capacity, the names of the officials, and the ratio of draft to bottled beer for some breweries.

The sales of beer in the United States in 1938 were as follows:

State	Barrels
New York	8,304,877
Pennsylvania	5,715,121
Wisconsin	5,570,487
Illinois	3,650,037
Missouri	3,604,616
Ohio	3,517,294
New Jersey	3,151,656
Michigan	2,643,435
Minnesota	2,512,517
California	2,382,598
All Other States*	10,307,702
Total	51,360,340

* Including Hawaii and Alaska.

Note by Abstractor.—This report does not have anything to do with wastes, but some of the statistical data are of interest as a guide to the brewing industry in general, including the names and capacities of breweries throughout the United States.

F. W. MOHLMAN

BOOK REVIEWS

Handbook on Sewage Disposal (Taschenbuch der Stadtentwässerung). By KARL IMHOFF. Eighth Edition (1939), 252 pages, 78 Fig. R. O. Oldenbourg, Munich, Publishers. Linen Binding, 6.50 Marks.

The new edition of Dr. Imhoff's well-known "Taschenbuch" includes 50 pages and 20 figures more than the former edition. Prof. Gordon Fair, of Harvard University, has collaborated with Dr. Imhoff to include the latest American data on such topics as gas production from sludge, oxygen demand of sludge, reaeration of streams, and activated sludge practice. The book contains, as usual, many interesting problems in whose solution the reader gains a firm knowledge of basic principles of sewage disposal. Complicated formulas or difficult mathematics are avoided, and many diagrams illustrate the discussions concisely and precisely.

The first 46 pages are devoted to sewerage, the next 22 pages to fundamentals of sewage disposal, and the next 145 pages to basic data for the design and planning of sewage treatment works. Then follows 10 pages of problems designed to bring out the important facts of the preceding discussion. Pages 227 to 245 include text, formulas and curves which present the principles of stream pollution and self-purification more lucidly than can be found in any other textbook available, either in English or German. A table of conversion factors ends the book.

The outstanding feature of this book of Dr. Imhoff's is the tremendous range of information he has assembled and compressed into this small volume. He has selected

the significant facts by observing the developments in all phases of sewage disposal, and weighing the merits or demerits of all so-called progress. Discrimination and keenness of foresight are essential for this task, and the careful reader will appreciate Dr. Imhoff's unique ability to differentiate between true and false progress in sewage treatment the world over. All those who can read German should get this book.

F. W. MOHLMAN

Technologie Des Wassers. BY F. SIERP, A. SPLITTGERBER AND H. HOLTHÖFER. With 421 illustrations. Published by Julius Springer, Berlin (1939). Price, Bound, 111.6 Marks.

This book of 745 pages is an outstanding contribution in the fields of water treatment, water softening, sewage treatment, and industrial waste disposal. It is particularly noteworthy for the last two topics, contributed by Dr. Sierp. The divisions of the book are as follows:

Topic	Pages	Author
Water Supply and Purification	1–208	Sierp
Sewage Treatment and Disposal	209–470	Sierp
Industrial Wastes	471–670	Sierp
Boiler Water	671–698	Splittgerber
German Water Law	699–719	Holthöfer

These subjects are treated primarily from the chemical viewpoint, with emphasis on the most recent processes of treatment or disposal. English and American practice is covered, as well as German.

Water purification includes discussion of the quality of water required for industries, the filtration of water, removal of oil, iron, manganese, acids, gases and hardness. Disinfection and sterilization processes include chlorine, ozone, ultraviolet rays, and the electrokatadyn process.

Sewage treatment is covered quite competently and thoroughly, including all of the latest developments in this field. There are, for example, discussions of the Jenks and Halvorson filters, the enclosed aerated filter, the magnetite filter, the flash drying system of sludge disposal, the Jung process of chemical precipitation and the Guggenheim process. (The abandoned Laughlin paper-lime-iron process is also included.) All types of activated sludge processes are described. Sludge digestion is treated in detail.

The most valuable feature of the book, however, is the section on industrial wastes. This is possibly because of the dearth of published material in this field, but mainly due to Dr. Sierp's authoritative knowledge of this subject because of his years of service in the Ruhr District, Germany's industrial center. Wastes from possibly fifty types of industries are described and processes for their treatment or disposal are discussed. The sections on iron pickling wastes, phenol wastes, paper mill wastes and distillery wastes are especially valuable.

The reviewer spent a pleasant day visiting Dr. Sierp in Essen in August, 1938, when he mentioned, in his modest way, that he was writing a book on sewage and industrial wastes. His casual reference to it gave no indication of the scope and encyclopedic detail of this valuable book. It is unfortunate that it is so expensive as to prevent purchase by any but a few persons in the United States. The reviewer has a few sixteen-page announcements concerning this book, which he will be glad to send to prospective purchasers.

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